PRODUCT ENGINEERING

FEBRUARY, 1948

BUICK'S NEW DYNAFLOW TRANSMISSION

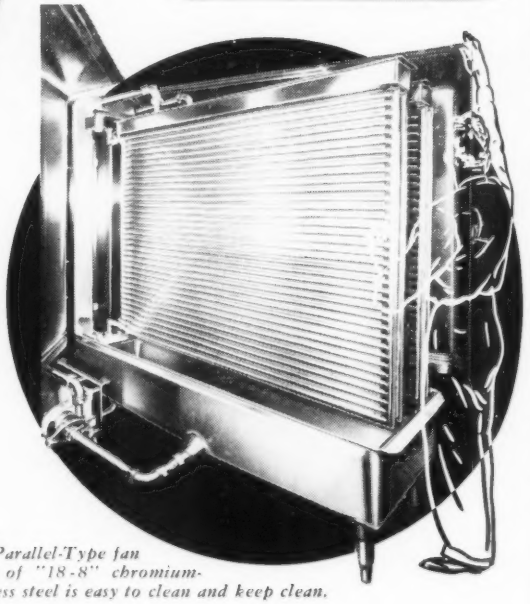
IN THIS ISSUE—Engineering Developments in 1947 + Dynaflow Transmission Design Details + Noise Analysis + Permanent Magnet Materials + Hydraulic Orifices

A McGraw-Hill Publication

When Product Purity is Essential

...take a tip from Dairymen

The above 300 gallon Vacuum "A&G" Buttermilk Machine used in a Baltimore, Md. creamery was fabricated from "18-8" chromium-Nickel stainless steel by Jensen Machinery Co., Inc.



This Jensen Parallel-Type fan cooler made of "18-8" chromium-Nickel stainless steel is easy to clean and keep clean.

Even the *least* contamination by bacteria spells D-A-N-G-E-R to processors of milk.

The faintest contamination from products of corrosion may affect the taste.

And that's why chromium Nickel austenitic stainless steel is used for so many pasteurizers, storage tanks, surface coolers, piping and other units for the dairy products industry.

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In addition, for many applications in various fields where resistance to corrosion, impact, wear and abrasion are required, "18-8" permits cutting bulk and dead weight without sacrificing strength or durability. Its great resistance to both high and low temperature effects is especially valuable.

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Product Engineering

VOLUME 19 NUMBER 2

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FRONT COVER—Buick engineers inspecting a cutaway section of the hydraulic torque converter unit of Buick's New Dynaflow Transmission. Left to right: W. R. Coughtry, engineer, chassis division; J. A. Nyland, staff engineer, chassis division; Edward T. Ragsdale, assistant chief engineer; Charles A. Chayne, chief engineer. Kodachrome courtesy Buick Motor Division.

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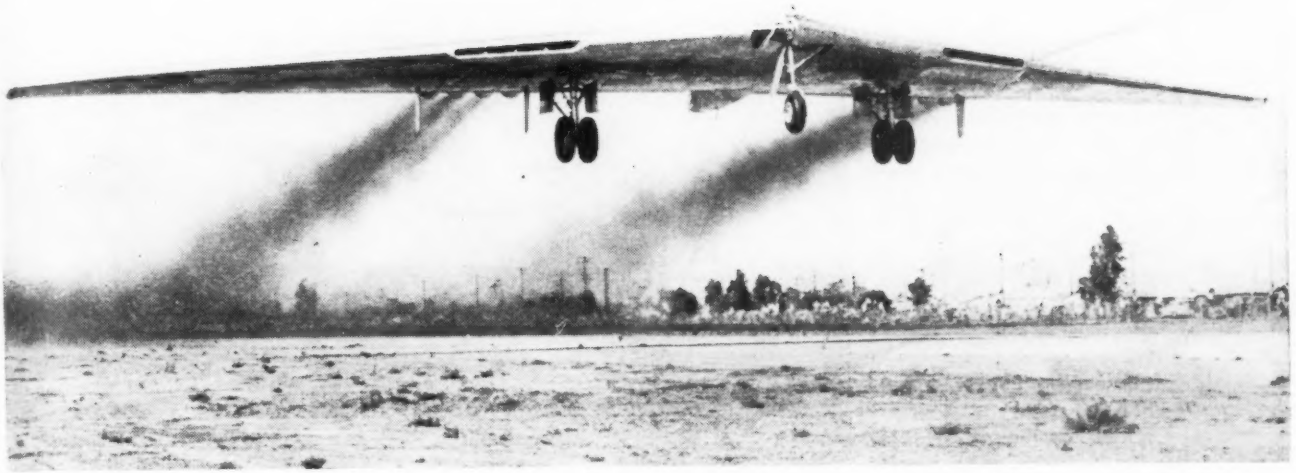
MARCH HIGHLIGHTS

MOTOR DRIVEN MACHINES. Special 32 page editorial insert, outlining load characteristics and mechanical factors to be considered in the design of motor driven machines to obtain efficient motor operation and to make possible the use of an economical type of motor. Included in subjects covered are clutches, couplings, gear drives, speed reducers and torque characteristics of standard motors.

GRAPHICAL DETERMINATION OF GEAR CONTACT RATIOS, by D. W. Dudley of General Electric gives a simple and accurate method of solving meshing diagrams by use of easily-constructed graphs.

DESIGNING WITH DOLLARS, by John Van Hamersveld, senior cost analyst of The Glenn L. Martin Company. The organization of cost data, on material and parts, for engineering use.



POWERED BY EIGHT TURBO-JETS, U.S. Air Force-Northrop YB-49 "Flying Wing" shows acceptance of jet engines in aircraft propulsion. Largest jet bomber in the world, YB-49's engines have a combined output of 32,000 hp. Wingspread of the plane is 172 ft; gross weight is 100 tons. The "Flying Wing" is shown above in its maiden flight at Northrop Field, Hawthorne, California.

Engineering Developments in 1947

1947 saw application and improvement of high-temperature materials. Production techniques included betatron X-ray inspection, induction heating, inert gas arc welding. Research was closely geared to fluid flow and supersonic flight.

HAROLD SCHOR
Associate Editor

PROGRESS IN MACHINES and materials during 1947 was reported by three large electrical manufacturing companies. In year-end evaluations of technical developments, the Allis-Chalmers Manufacturing Company, the General Electrical Company, and the Westinghouse Electric Corporation, revealed significant improvement in electrical and mechanical components, properties of metals and other materials, as well as in research and testing facilities.

MATERIALS

Rare metals often become important after long peaceful periods as scientific curiosities. Like uranium and molybdenum, zirconium has been a metal little known outside lamp-research laboratories. Malleable zirconium has been produced by Westinghouse for several years in limited quantity at a cost of approximately 30 to 40 dollars per ounce. But new and much cheaper ways have been found to produce it. One is the outcome of research on electronic tubes.

Its behavior as a "sponge" for oxygen nitrogen gives zirconium its appeal to electronic tube engineers. Placed in a tube, a small quantity of the metal "cleans up" stray oxygen or nitrogen molecules that appear during the early life of the tube from within the metal and glass parts and which would be destructive to normal functioning of the tube. Zirconium soaks up astonishing amounts of these gases and does not give them up even on prolonged heating. Zirconium absorbs hydrogen as well, but releases it when hot. This suggests the possibility of using zirconium in tubes that require a hydrogen gas balance.

Zirconium is a moderately light metal, medium soft (about 80 to 150 Brinell, 40 to 80 Rockwell B) depending upon the process used. Although it absorbs oxygen in prodigious amounts it does not form an oxide at room temperatures. It is a white silvery metal with a beautiful luster, and takes a high polish which it retains permanently because it does not oxidize or combine with common corrosive gases such as sulphur.

Germanium, among the rare of the elements, belongs to a small group of solids known as semiconductors; it possesses electrical properties intermediate between those of metals and insulators. The unusual current-conducting properties of germanium were first put to use in a crystal rectifier for radio communication at ultra-high frequencies. Then it was observed that adding suitable "donors" resulted in unusually high burn-out characteristics, whereupon the unit was adapted to high-voltage rectification. It offers

possibilities in portable electric equipment, because of its small size and weight and it does not have the alternating-current hum of hot-cathode tubes.

Chemical and metallurgical developments broadened the scope of applications for plastics, silicones, insulating materials, and metallurgical products, and promised to open still more fields in the coming year. In the field of plastics there was the development of two new compounds—a phenolic and a heat-resistant molding compound. The first all-plastics rowboat was designed and manufactured and a size record was set in making a 650-lb laminated plastic part for a synchrotron.

There were many new applications of silicone oils, a new use for "bouncing putty," and a new silicone adhesive.

Metallurgical developments included the introduction of new permanent-magnet assemblies, design of an ion trap for television tubes, a magnetic vibrator assembly to test magnets, and improvements in various alloys.

Resin and insulation advances included a solventless, cold setting, casting resin; a varnished cloth combining insulating and adhesive properties; and improvements in synthetic resins for enamels.

Combustion-chamber liners and buckets in gas turbines of jet-propelled aircraft may have a longer life by being coated with high-temperature ceramic glazes. Such an application of ceramics is still a research development, however, and has not been used in gas-turbine production. Investigations of solid ceramic turbine buckets were also being made.

Coating combustion chamber liners and turbine buckets in gas turbines of jet-propelled aircraft with high-temperature ceramics may give the turbines longer life, research investigations indicated.

COMBUSTOR CASING and flame tube of a 2000 hp gas turbine generator. The corrugated sections in the flame tube admit cooling air which protects the tube from the hot core of combustion gases. New materials withstand high temperatures without creep.

Aviation

The past year was significant in aircraft gas-turbine progress, and in the development of electric equipment for the aviation industry. Many new jet-powered military airplanes took were introduced and made remarkable performance records. Adaptations were made of wartime designs of electric equipment for use in peace, and research and fundamental development went ahead at a rate comparable with that maintained during the war years.

The most noteworthy air record was that of the Douglas D-558, the Skystreak, equipped with a single axial-flow turbo-jet engine, it set a world's speed record of 650.6 mph.

Jet-propelled airplanes of the year included two four-jet bombers, the North American XB-45 and Consolidated Vultee's XB-46; Boeing's XB-47 and the Martin XB-48, each with six-turbo-jets; and Northrop's huge YB-49 Flying Wing, powered with eight jets. In the single-engine fighter-plane class there was North American's XP-86 with swept-back wings.

Boeing's Stratocruiser, initially flown in July, became the first turbo-supercharged passenger plane. Boeing's new B-50, larger and more powerful than the B-29, likewise was turbosupercharged for high-altitude peak performance.

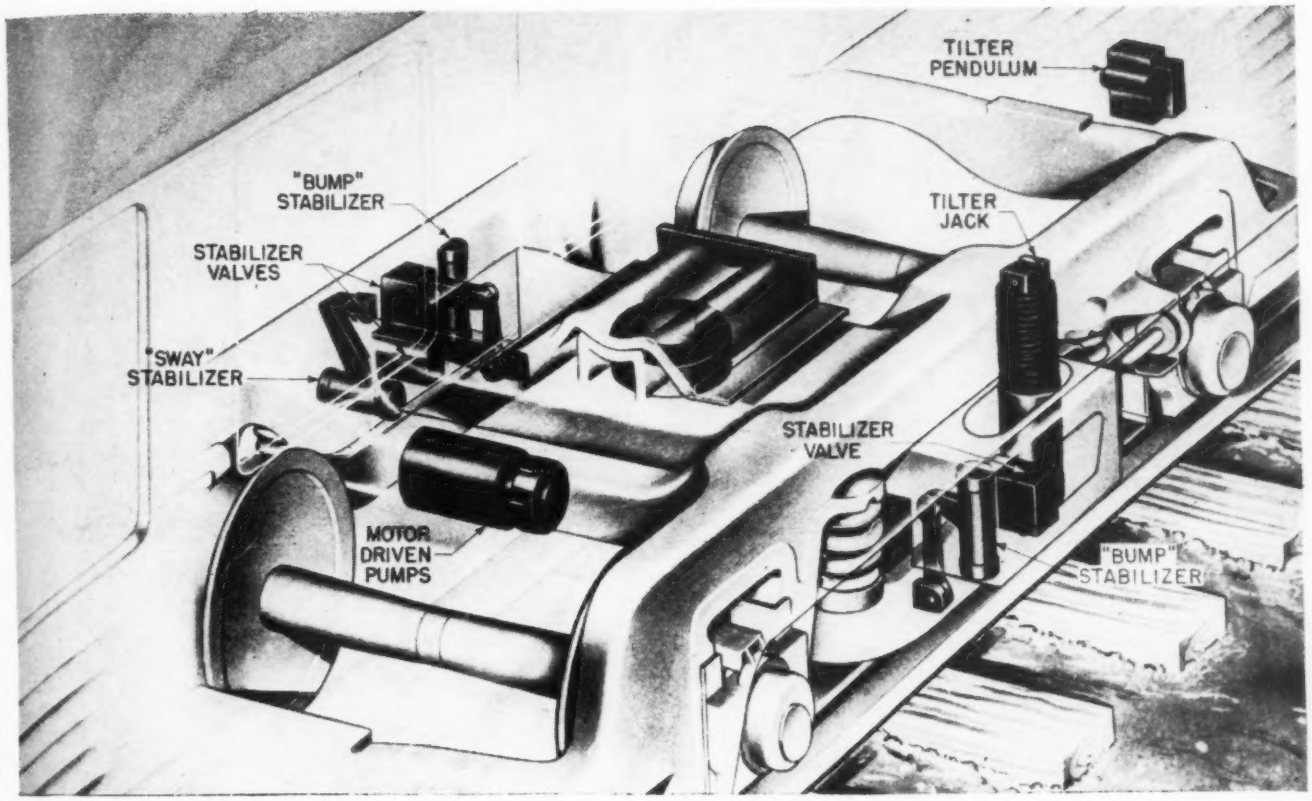
Wartime activity with gyroscopic stabilizers for tank guns and airplane gun turrets has led to a new automatic pilot for airplanes that is unaffected by any maneuver of the plane. The automatic control can be set to cause the plane to climb or descend at a given rate, to fly at a fixed level, or to adhere to a prescribed course, allowing the pilot to attend the remaining multiplicity of duties concerned with his ship.

The new device, the Gyropilot, employs three separate but coordinated gyroscopes, one for each principal axis of motion. These are rate gyros, so-called because they are responsive to change in angular velocity. Position gyros, customarily used in automatic pilots, are sensitive to change in absolute angular position. Rate gyros are fixed to the plane and allow it to loop the loop and barrel roll, if desired, without loss of control. The Gyropilot is not adversely affected by high acceleration rates, which suggest its possible use on guided missiles and pilotless aircraft. Because the Gyropilot (which is still in the experimental stage) is small and light, it is expected to be applicable to light commercial and private planes as well as military craft.

Another safety development was a VHF (very high frequency) transmitter operating in conjunction with the plane's existing radio. This enables the pilot to talk to control towers at a frequency of 122 megacycles, where clear communication is possible, despite natural and man-made static. A small, efficient whip antenna was developed for the transmitter.

Turbines, Jets, Rockets

Gas turbines—first used in jet-propelled aircraft—were undergoing exhaustive tests in 1947, for locomotive, marine and stationary power-plants. Rocket propulsion motors, their con-



SHOCK ABSORBER for trucks or railroads. Installed on a railroad car, the screw jack or tilter jack tilts the body of the car to the proper position as it enters a curve. The two smaller bump stabilizers on either side of the truck compensate for bumps or dips in the track. The sway stabilizer moves the truck wheels from side to side, while holding the car body still, to compensate for weaving.

touring, fuels and controls, received much attention.

A 2000 hp experimental gas turbine has been tested by Westinghouse. No fundamental weaknesses appeared. By late fall, the unit had run more than 600 hours, including about 100 hours at full load and 300 hours of cyclic operation simulating locomotive service. This consisted of one-half hour successively at each of three conditions; idling, half load, and full load. The machine has operated at the full design temperature, 1350 F, without measurable creep, with no distortion difficulties, without oxidation or any evidence of distress of the special turbine blade material.

Gas-turbine engineers are preparing for units two or three times larger for both locomotive service and industrial use. No basic change in structure is contemplated. Engineers feel that the next units will require no new materials; with present knowledge temperatures can be safely increased another hundred degrees.

A test station where studies will be made with static tests on rocket propulsion motors having up to 50,000 lb thrust—about one-half million—was erected near Schenectady as part of the General Electric—U. S. Army Ordnance Department joint long-range rocket research program. Other laboratory investigations of this and allied problems—aerodynamics, propellents, controls—were in progress. Among developments were a new telemetering device for returning scientific and operating information from the speeding missile to the ground, enabling plotting of trajectory data, and a flight simulator for ground testing of rocket controls.

Railroad Stabilizer

A shock absorber that irons out the bumps in railroad tracks or highways has been developed by Westinghouse Electric Corp. research engineers. The new stabilizer is designed to: Eliminate more than 60 percent of the bumps and sway caused by irregularities in tracks or roads; enable trains to take curves at more than 25 percent greater speeds.

Floating weights that feel up-and-down and sideway motion, and a pendulum that senses the pull of centrifugal force and gravity, working together or separately, detect and respond to bumps or side-sway in 0.003 second. They anticipate the movement and correct it before it is felt by the train or bus passengers.

The stabilizer automatically moves the car trucks or bus wheels up and down to compensate for bumps in the road surface. Train wheels are moved from side to side to correct for track weaving. A tilter banks the body as it rounds a curve. On a railroad car, this is done by six hydraulic cylinders and a pair of motor-driven screw-jacks. Four cylinders take care of vertical bumps and two side-sway.

When the car comes to a bump or dip in the track the floating weight instantly "senses" the motion of the body as it begins. The movement opens one valve and closes another, causing oil under high pressure to flow into the proper cylinder. The piston in the cylinder moves with just enough force in the right direction to counteract the bump and hold the car body virtually motionless. This takes place in three one-thousandths of a second. The same type of action moves the wheels right or left to correct for side-sway and the car body moves forward in a straight line.

When the train enters a curve, the gyro-controlled pendulum regulates two electrically-driven screw jacks, placed at diagonal ends of the car body. If the speed is not quite right for the bank of the track, centrifugal force swings the pendulum. This closes an electrical contact to operate the two jacks which immediately tilt the car body to the correct bank angle. The permissible speed on curves depends

THESE COPPER FINS inserted at intervals into the hottest part of the motor steel laminations help conduct the heat to the cooling air and make possible smaller totally-enclosed motors.

CURRENT passed through a transparent conducting film in this airplane window "sandwich" generates heat enough to keep ice or frost from forming to obscure the pilot's view.

on the design of the locomotive, but even with this limitation the tilter will make possible 25 percent overspeed without passenger discomfort.

The same equipment used on railroad cars, modified slightly, can be applied to large passenger buses. In buses, however, the system will be simpler because of the omission of lateral sway stabilizers, since buses have no swing link suspension. Although the application of the new stabilizer to automobiles is more remote, parts of the new system were used for months on a large sedan.

Motors

Among special motors developed industrially were three for research purposes. Only $1\frac{3}{4}$ in. in diameter and six in. long, they operate at 80,000 rpm and produce 1/10 hp.

Copper fins extending from the stator core, to improve motor cooling, have culminated in a family of totally-enclosed "copper-fin" motors. These include the range from 125 to 1000 hp and may be extended even further. This design is based on the premise that accumulation of heat in the interior of a non-ventilated, totally-enclosed motor can be avoided by using copper punchings spaced at intervals between the steel laminations. The copper disks take up about the same space as do cooling air ducts on open motors and do an equivalent job of heat dissipation. Consequently, totally-enclosed motors built on this principle are much smaller than the conventional type. Special motor controls were designed for gaseous conditions and machine tools.

Testing and Measuring

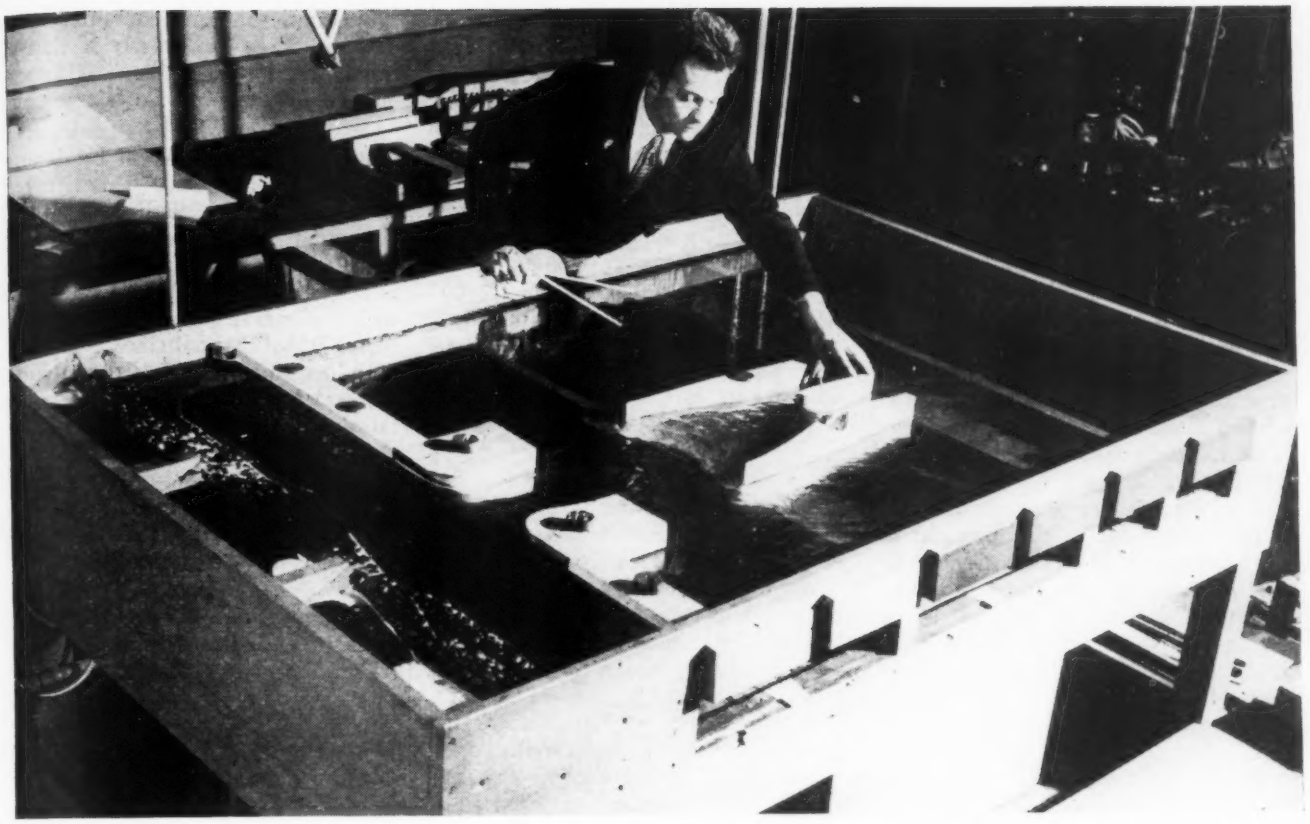
A close analogy between two-dimensional air flow and the behavior of surface waves in water was found, when the depth is small compared to the wavelength. This fact was put to work in a water table developed for both qualitative and quantitative studies of fluid flow. To study the flow of gases over specially designed surfaces such as ram jets and rockets, it was found helpful to construct a small model, place it on the water table, and observe the stream line of the water flow around it.

A horizontal surface of plate glass is provided with means for altering the inclination. A pumping system circulates the water, and acceleration is produced by means of a dam with sloping spillway. Depths are measured by means of a depth gage and by coating model sections with a water-soluble dye.

In studying the flow of gases over specially designed surfaces, such as in ram jets, rockets, etc., it is helpful to construct a small model, place it on a table, and observe the stream line of the water flow around it. Quantitative measurements of depths give information regarding pressure and temperatures in full-scale air flow. The water table is used for visible flow demonstrations, for quantitative investigations of lift, drag and moment of airfoils, and for studies in supersonic diffuser design.

A differential analyzer, placed in operation by the University of California at Los Angeles, made it possible for one man to solve in two weeks an intricate mathematical problem that otherwise might require 17 man-years of effort. It will be used in such commercial problems as the analysis of fluid flow in steam and gas turbines, the determination of torque and current oscillations in motors after disturbances, and the study of airplane landing shocks that would otherwise be too destructive. The machine is similar to those used during the war in studies of radar, hydrodynamic flow, rotating machinery, airplane stresses, speed governors, and in obtaining trajectory data for firing V-2 rockets at White Sands, New Mexico.

For electrical measurements there



STUDIES OF FLUID FLOW, qualitative and quantitative, are carried out on this water table. Table design is based on close analogy between two-dimensional air flow and behavior of surface waves in water when depth is small compared to wave length. Supersonic velocities are studied by observing flow of water around a model, simulating surfaces of rockets and ram jets.

was developed a two-element cathode-ray oscillograph and camera, incorporating automatic developing and projecting, for rapid testing with high voltage surges. A millionth-of-a-second surge can be photographed, the picture developed in 24 seconds, and the record then projected. Also of interest to photographers was a new photoelectric exposure meter "with a memory". It is operated simply by pressing a button, setting the pointer, and reading the exposure. It is vest-pocket size.

To the mass spectrometer and its variant, the leak detector, there was added a process control spectrometer especially designed to monitor and control process streams of mixed gases, keeping a continuous check on the presence of as many as eight individual components of a mixture.

A new machine capable of taking x-ray motion pictures at high speed opens many new fields of research. What happens to the human body when subjected to rapid accelerations, such as in the jet or supersonic airplanes? What is the mechanism of deposit of metal from an arc-welding rod? Or the actual events within a carbon arc? These and many more in such fields as ballistics, machinery motions, human and animal physiology are brought within a range of visual study by a new x-ray motion picture machine that can take 10 millionths of a second exposures at the rate of 150 per second.

The x-ray tube itself is different only in minor details from tubes used in other x-ray service, the power supply is new and is based on techniques developed for radar. By use of radar-type controls, operating at low voltage, and "Hipersil" (ceramic) core transformers developed for radar, pulses of about 5000 kw are supplied to the tube for about ten microseconds every hundredth of a second. This peak power is a thousand times greater than conventional x-ray machines.

Production Techniques

Typical of product improvement obtained with induction heating was the surface-hardening of lathe bed-ways to increase machine-tool life; the use by farm-equipment manufacturers to produce longer-life blades for mowing machines; and its use by automotive manufacturers to reduce wear on such important parts as valves, pins, cams and shafts.

In the frequency range of 3 to 40 megacycles there was steady growth as operating experience with pilot production units in many plants demonstrated where quality improvement or cost reduction can be obtained through use of dielectric heating.

Among interesting furnace installations was a 630-kw roller-hearth copper-brazing furnace, 185 feet long, for brazing plate-type evaporators for industrial refrigeration; it seals two steel sheets in sizes up to 2-½ by 12 feet. Another was a 9600-cycle induction furnace for annealing and coating bright steel strip in widths up to 54 inches, at a rate of 20,000 lb per hr.

Most interesting new trend seen in dielectric heating is the use of microwaves—radar frequencies. The early laboratory work with the use of such extremely high frequencies for heat-treating thin sheets, for curing thin synthetic films, or for curing insulation on wire as a continuous process has been most promising. The techniques for this work are borrowed directly from radar and involve such radar components as magnetrons and wave-guides.

At least one multi-million dollar plant was built with the production of the product based on radio-frequency heating. Without this process, this machinery plant which uses electronic generators for induction-hardening of gears, shafts and similar machine parts, is inoperative because no provision has been made for alternative methods of

heating. This is evidence of industry's confidence in radio-frequency heating.

In the recent months dielectric heating has been put to work in the wood industry. Big panels and timbers are made by edge gluing small ones and dielectrically curing the glue, sometimes as a continuous process. The result is a utilization of small pieces of lumber and increase in product strength and reduction in overall cost of finished product. One radio cabinet maker is currently building a cabinet in which all 28 pieces are held together solely by dielectric-cured synthetic glue and forms the laminated curved front as a step in the process. The result is better appearance and elimination of many steps in production with consequent cost savings.

Of great value in the manufacture of magnetrons and other devices requiring precision welding was an argon-shielded arc-welding apparatus. Because of localization of the heating, stock as thin as 10 mils has been successfully welded, and welds can be made safely very near to glass parts.

A constant speed is maintained by a unit having a dial speed control. The object to be welded is chucked in the lathe and serves as one of the electrodes. The other electrode is surrounded by a tubular jacket through which a stream of argon is passed from a pressure tank—argon maintains a constant arc voltage independent of arc length. The current is carried by the gas stream instead of by the arc itself as in the ordinary metal arc, and the energy required is relatively low. Instead of transferring metal from the electrode to the work, the shielded arc applies sufficient heat locally to fuse the metals that are in contact. The method is free from bubbles of trapped gas.

For welding alumnium, magnesium, and beryllium copper without use of flux, there was developed a new argon gas welder having all components built into one compact, drip-proof case, with electric and gas and water connections at convenient outlets.

Nucleonics

Last year was devoted more to arrangements than to production, so far as nuclear energy is concerned.

At Schenectady the Knolls Atomic Power Laboratory of the Atomic Energy Commission was under construction, for operation by the General Electric Company in applied research and engineering development for industrial atomic power. Near Richland, Wash., G. E. was the operating agency at Hanford Engineering Works in plutonium production and in physical and chemical research.

There was, however, at least one important announcement during the year about atomic energy. The Los Alamos, New Mexico, experimental station of the AEC revealed that it had been found possible to use pure plutonium—an element unknown a few years ago—to operate a relatively small reactor or "pile," without a moderator to slow down fast neutrons.

Fast x-raying of steel—ten inches in just a few minutes—will be done in the Naval Ordnance Laboratory at White Oaks, Md., with a 10 million-volt betatron. First of its size for industrial use, it will be employed in radiography of castings and weldments of naval guns, directors, armor plate, and other ordnance equipment. The machine is a small version of General Electric's 100 million-volt betatron, but is considered more suitable for industrial radiography of thick specimens. Betatrons with higher energies, although invaluable in nuclear research, have beams too narrow for inspection at close range.

Also under construction were a 50 million-volt betatron for the National Bureau of Standards components of a 70 million-volt synchrotron for Iowa State University (combining techniques employed by the earlier betatron and cyclotron, the synchrotron accelerates electrons in a doughnut-shaped vacuum tube, first by magnetic field and then by an electric field); two 100 million-volt betatrons for the University of Chicago and the Clinton Laboratories at Oak Ridge, Tenn.; and $3\frac{1}{2}$ million-volt electrostatic proton accelerator, also for nuclear research.

ANNEALING an automobile brake arm, previous to forming, is done by one manufacturer on a 20 kw induction heater, at the rate of 1800 pieces a minute.

A LEAK DETECTOR, based on the mass spectrometer developed in atomic research, is shown being used on a refrigerator production line, for testing the piping system.

Gear Tooth Inspection Method As An Index of Performance

Analysis and interpretation of inspection data obtained by the pin measurement method and the master gear or rack method of checking the accuracy of gear tooth elements.

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METHODS OF CHECKING GEARS for size and accuracy have received considerable attention by engineers. When writing acceptance specifications it is wise to keep in mind the inherent limitations and advantages of the method used.

Before going into the different phases of this problem, it might be well to consider the elements that constitute a good spur gear, and to outline some of the fundamental principles of the involute curve, which is the one used for tooth profiles in the vast majority of fine pitch gears.

1. Involute gears impart, one to the other, uniform angular action irrespective of variations in center distances.

2. The involute is dependent only on the size of its base circle and the rate of motion transmitted from one involute to another depends only upon the relative sizes of the base circles of the two involutes. This rate of motion is in inverse proportion to the sizes of the two base circles.

3. The common tangent of the two base circles is the line of action. Tooth action takes place only along this common tangent.

4. The intersection of the common tangent to the two base circles with their common center line determines the pitch line of the two involutes. No involute has a pitch line until it is brought in contact with another involute, or a straight line constrained to move in a defined fixed direction.

These are four of the fundamental laws of the involute curve. There are others, which need not be mentioned here for the purpose of this discussion. It is quite obvious that the common notion, that involute gears in themselves have definite and concrete pitch circles, is erroneous and based on the wrong concept of the properties of the involute curve. Gears must mesh with each other or a rack, before a pitch line can be established.

It is perfectly possible by analytical methods to take certain measurements on a gear, which is to be meshed with another, and be reasonably sure that when placed on their proper centers, the two will operate satisfactorily. For instance, it is possible to check the tooth thicknesses of the gears at the theoretical pitch diameter, which is actually the quotient of the number of teeth divided by the diametral pitch, by means of gear tooth calipers. It is also possible to arrive at the same result in a more refined manner, by placing accurately made pins in the tooth spaces, and measuring over the pins. This technique is well known and there are several systems of pin measurements of gears in current use.

The measurement of tooth thickness, either by means of tooth calipers or pins, gives only one of the elements necessary to control accuracy in gears. This measurement is also subject to errors resulting from the improper contact of the calipers or pins on the profiles of the gear tooth, since the spot on the tooth profile where the pin sets and where measurements are taken is assumed to be perfect in every respect. Actually, the tooth profiles may have slight depressions or protuberances at this point. Also the feed marks on opposite sides of the teeth where the pin contacts may be of different magnitudes.

In spur gears there are four distinct types of errors that affect uniform angular motion. These are: Eccentricity, profile error, variations in tooth spacing and in tooth thickness.

In addition to these there is another type of error, common to all types of

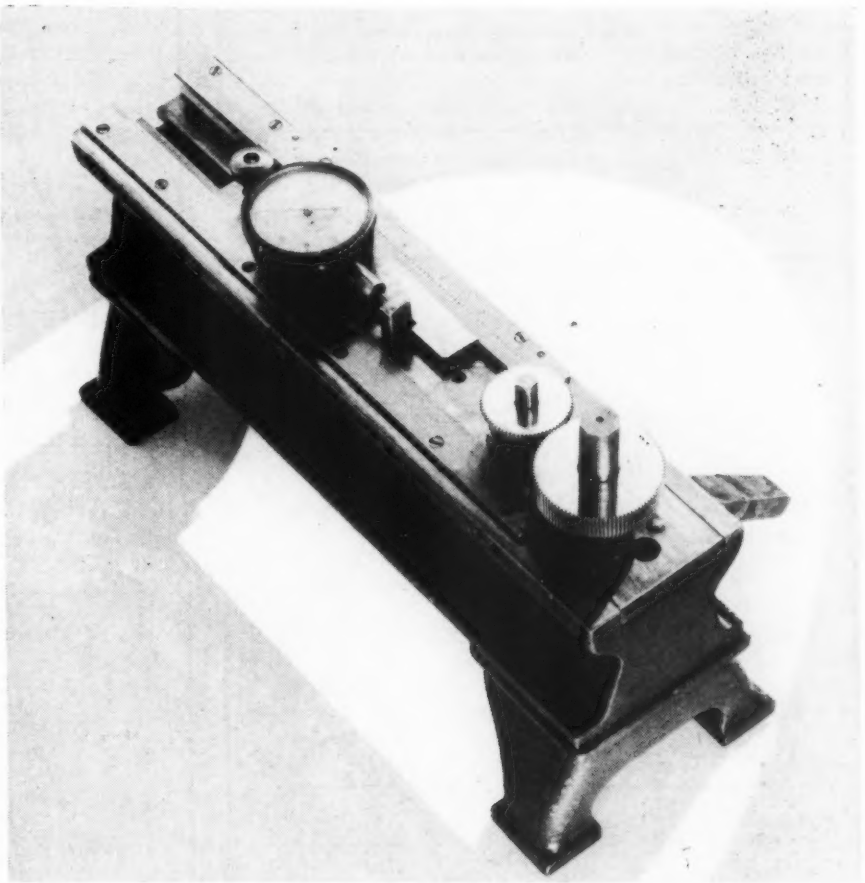


Fig. 1—Composite check test fixture for measuring deviations in center distance during the rotation of a test gear with a master gear. Gage indicates faulty tooth conjugation.

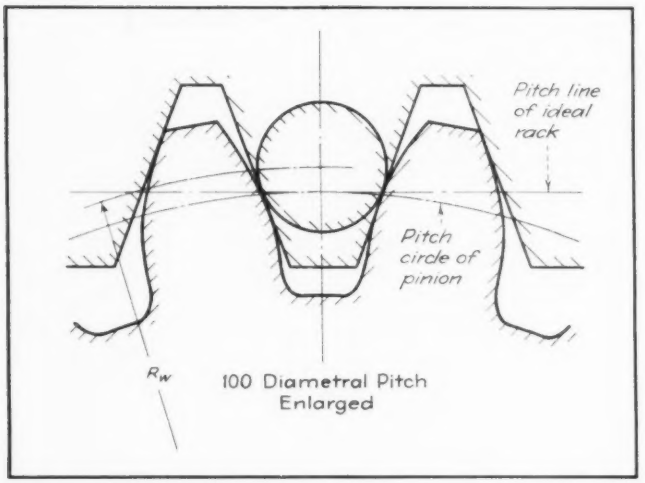


Fig. 2—An ideal 20 deg pressure angle rack in mesh with an ideal 20 deg pressure angle, 20 tooth pinion. The relative position of a 0.01728 in. measuring wire is also shown.

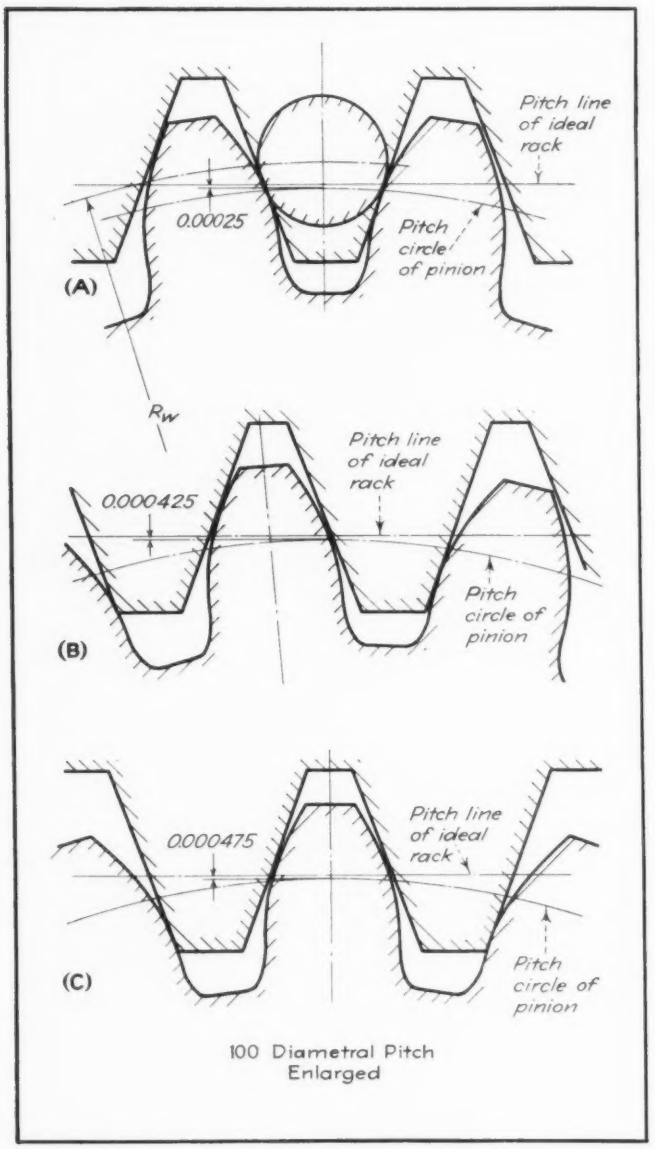


Fig. 3—Ideal 20 deg pressure angle rack in mesh with a 20 deg 30 min pressure angle, 20 tooth pinion. (A) Rack tooth in center phase of contact. (B) Receding phase of tooth contact. (C) Pinion tooth in center phase of contact.

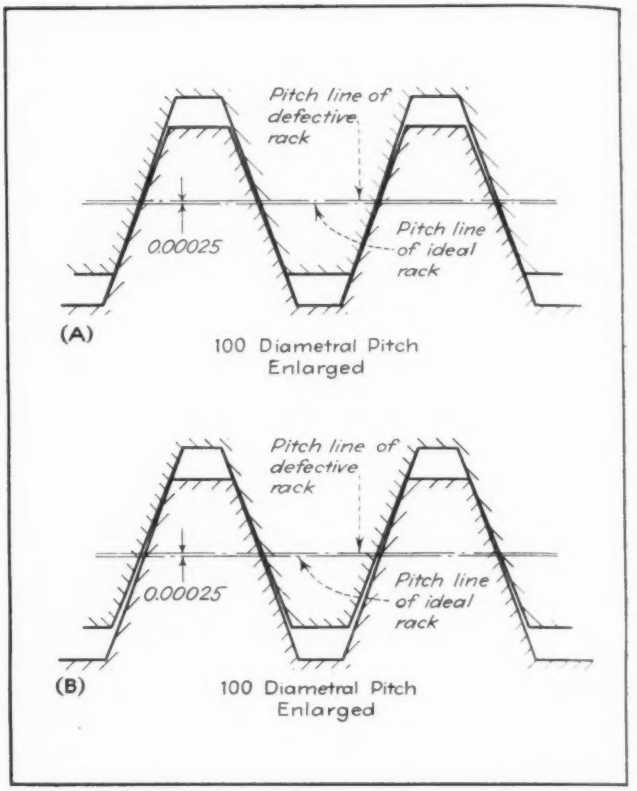


Fig. 4—Two racks in mesh. (A) Lower rack with correct 20 deg pressure angle. Upper rack with incorrect 19 deg 30 min pressure angle. (B) Lower rack with correct 20 deg pressure angle. Upper rack with incorrect 20 deg 30 min pressure angle.

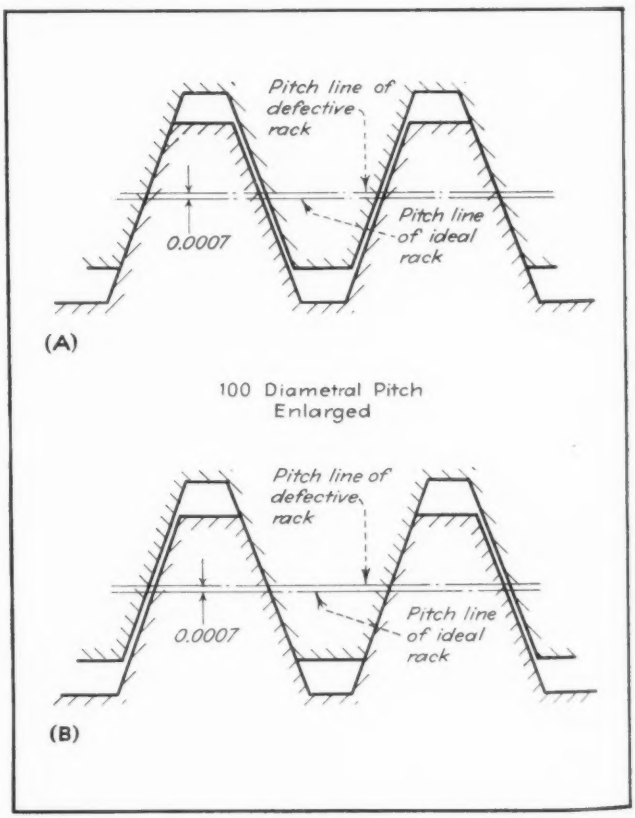


Fig. 5—Two racks in mesh. (A) Lower rack is a standard 20 deg pressure angle rack. Upper rack is a 20 deg pressure angle rack with tooth 0.0005 in. thin. (B) Lower rack is a standard 20 deg pressure angle rack. Upper rack is a standard 20 deg pressure angle rack with tooth thickness increased 0.0005 inch.

gears, known as lateral runout or "wobble." This is usually mainfested as eccentricity, although it has the same effect as a combination of profile error and eccentricity.

The most satisfactory manner of checking the influence or composite effect of these errors against the mating gear is to duplicate as closely as possible the actual operating conditions of the gears. This can be done by rotating the gears to be checked against a master gear or rack on a suitable fixture. A typical fixture is shown in Fig. 1, it should include: (*A*) A fixed pin for mounting an accurately made master gear; (*B*) A part, upon which the gear to be tested is mounted, that is free to move parallel to a line through the centers of the meshing gears; and (*C*) A device for measuring any deviation in the center distance that occurs when the meshing gears are rotated.

An analysis of the difference between the pin method of checking "so called" pitch diameter of a gear and pitch diameter as measured with a master gear on a variable center distance fixture discloses that only when conditions are ideal do the two methods agree with each other. Even when an appreciable profile error exists in the work, the pin measurement may give the same reading that is obtained in an ideal gear. A check against a master gear on a variable center distance fixture, on the other hand, shows a separation over the nominal distance resulting from profile error. Furthermore, inasmuch as the influence of this type of error on center distance displacement varies at different stages of contact of the gear with the master, the recurring difference in the magnitude of this separation is reflected as a jump or flicker on the recording medium of the instrument on which the gear is checked. This flicker, which is the result of improper tooth conjugation, can be evaluated for any set of given conditions.

An ideal gear and master in mesh at theoretically correct centers are shown in Fig. 2. Superimposed on the gear is a pin of the proper size for measuring the tooth thickness. Radius R_w is the distance from the center of the pin to the center of the gear. No separation between the pitch line of gear and master exists here because all conditions are ideal.

The same ideal master meshing with a gear that has a similar profile error on both sides of the teeth equivalent to plus thirty minutes on pressure angle is shown in Fig. 3(*A*). This error is well within the tolerance of Class A generating tools for this pitch. Radius R_w is, for all practical purposes, exactly the same as in Fig. 2, however, the centers of the gear and master have been displaced approximately 0.00025 in. in this phase of tooth contact. Fig. 3(*B*) shows the same gear and master in the receding phase of tooth contact. The separation at this point is approximately 0.000425 in. Fig. 3(*C*) shows the same gears in mesh in the center of contact phases. At this point the separation amounts to approximately 0.000475 in. Thus it is apparent that profile error causes a separation of from approximately 0.000475 in. to approximately 0.00025 in. and a resultant flicker of 0.000225 in., which is evidence of improper tooth conjugation.

In Figs. 4(*A*) and (*B*) are shown the resulting separation in center distance of two racks, which takes place when a perfect rack is meshed with; first, one which has a plus pressure angle of thirty minutes; and second, one which has a minus pressure angle of thirty minutes. This shows that regardless of whether the profile error is of a plus or minus nature, the separation in centers is of the same magnitude, approximately 0.00025 inch.

In Figs. 5(*A*) and (*B*) are shown the effect of incorrect spacing when only one tooth is thicker or thinner than all of the rest, because of a circular pitch error. The separation is exactly the same in both cases, approximately 0.0007 in. for a difference of tooth thickness of 0.0005 inch.

In Fig. 6 is shown the resulting separation caused by an unequal profile error on opposite sides of the teeth of a 20 tooth pinion coupled with a spacing error.

This analysis does not show all of the possible combination of errors, as obviously such a study would be burdensome and would not serve any useful purpose. The values given in this discussion are those actually encountered in practice. No errors were assumed to exist in the master gear. It is known that master gears are not perfect. For the simplicity of comparison of the two methods of checking gears, this seemed the best approach. By the same token a master rack was used in place of a master gear.

The conclusion of this study is quite obvious. Pin measurements of gears have their limitations. Only one of the several important elements is checked and this without complete assurance of accuracy because of measurements are based on the unknown factor of accuracy of the tooth profile at the point of contact of the pin.

It is further demonstrated that in order to check all of the important errors in gears the inspection method should duplicate, as closely as possible, the operating conditions of the gears in action. This can best be done by means of a master gear or rack on a variable center distance fixture. Gears checked in this manner frequently show a larger pitch diameter, that is, thicker teeth, than that obtained by the measurement over pins. The two methods do not necessarily coincide and should not be used interchangeably without an understanding of the factors contributing to the discrepancies. The inspection of a gear by meshing it with a master, as mentioned in the foregoing discussion, checks the several elements that make the gear good or bad when assembled in its mechanism, whereas, the pin measurement method measures only the tooth thickness without regard to the other elements. The chief use of pins should be in determining size during the setting-up operation. They should be used to supplement rather than replace the much more inclusive composite check.

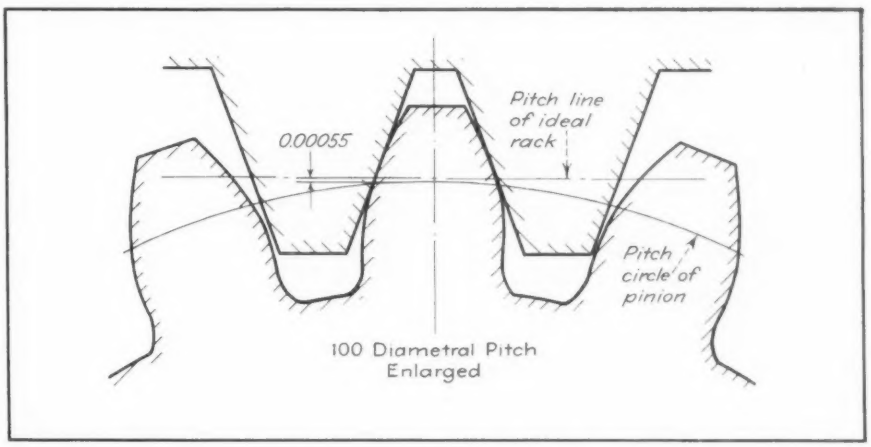


Fig. 6—Separation between an ideal 20 deg pressure angle rack in mesh with a 20 tooth pinion having a pressure angle of 20 deg 30 min and 19 deg 30 min on opposite sides of each tooth, and an increased tooth thickness of 0.0005 in. on one tooth.

Flexible Couplings for Shafts

Design of flexible couplings to be weakest unit in connected machinery so they act as protective devices. Couplings designed to satisfy requirements other than power transmission. Interpretation of coupling wear in systems.

JOHN H. SCHMID

Vice President, Charge of Engineering
American Flexible Coupling Company

MUCH CAREFUL DESIGN EFFORT is wasted when a driven machine is connected to a prime mover without careful consideration of the flexible coupling to be used. A recent survey indicates that little effort is expended when specifying flexible couplings. The coupling is thought of as a minor element because some form of coupling must be used in every direct hook-up. The painstaking efforts of both the installation designer and the coupling manufacturer are wasted when the units are incorrectly used.

Coupling Functions

The primary and apparent purpose of a flexible shaft coupling is to connect two shafts for the direct mechanical transmission of power with as little loss and lag as possible. Experience has shown a flexible coupling to be also a protective device and an indicator of impending trouble for the complete installation. A properly installed coupling is fulfilling its designed function when it shows wear and should not be condemned as faulty.

As a protective device, a coupling must compensate for bearing misalignment, reduce shaft flexing and protect the machine and prime mover bearings from stresses and wear resulting from misalignment. As an indicator, it should absorb the induced stresses and show when they are excessive. A flexible coupling can be likened to a circuit breaker or a fuse because it is installed to transmit power but is designed to be the weakest link in the system. Like the fuse, the coupling should absorb the damage from overload and should indicate that overloading has occurred.

A flexible coupling is not designed to be used to effect a change in the direction of shafting. It should be installed, as near as possible, in perfect alignment. When shaft misalignment does occur from shifting equipment, shaft flexing, loose mountings, vibration or other causes, the coupling can compensate for the misalignment until corrective maintenance can be effected. Couplings that do not transmit misalignment stresses to bearings of the connected machines, do not exhibit any appreciable power loss themselves.

Coupling Types

Many methods are used to achieve flexibility in shaft couplings. Some of the most common and effective flexible couplings are based on the Oldham principle. The basic Oldham coupling is made of three parts. Each of two identical parts, as shown in Fig. 2, has two planes, parallel to each other and to the shaft centerline, at an equal distance from the rotational center of the shaft. One of these parts is secured to each shaft with the pairs of parallel planes at right angles. The square space inclosed by the four planes is filled by the rigid, power transmitting part. The floating center member compensates for angular and parallel misalignment, or a combination of the two. The only reactionary stresses that can be set up in this type coupling are those resulting from frictional forces between the sliding members. The friction forces in the coupling can be minimized by adequate lubrication.

A refinement in this basic design, see Fig. 2, is the installation of replaceable bearing strips on the sides of the floating member. These bearing surfaces can be inspected periodically and replaced without disassembling the coupling. Oldham-type couplings can be used where bad misalignment conditions are anticipated.

The gear-type coupling shown in Fig. 3 is also flexible through its design. The basic gear-type coupling usually has a hub member for each shaft. The external spur gear teeth on these hubs are centered on and parallel to the shaft. The hubs are connected by a two-section sleeve having two sets of internal spur gears that engage the hub gears. The meshing gears have a slight amount of clearance and are crowned so that each set can rock slightly on its mating gears. This rocking movement is the only motion between the gears and the unit might better be designated a "spline coupling." Within the limits of the rocking motion, the sleeve member is full floating and will compensate for both angular and parallel misalignment. Frictional forces between the teeth, which can be lessened by lubrication, are the only reactionary stresses set up in this unit. Gear couplings can be used where speeds are in excess of usual motor speeds and where expected misalignment will be slight.

Within its limits, a gear coupling will absorb misalignment as effectively as Oldham-type couplings. However, the total misalignment that a gear coupling will absorb is much less than that for an Oldham-type coupling. A graphical example of this characteristic difference is shown in Fig. 4. The charts were taken by a recording wattmeter when the two types of coupling were subjected to differing amounts of misalignment on a test stand similar to that of Fig. 1. A gear coupling does not indicate dangerous misalignment conditions as readily as the Oldham-type coupling since any wear will be distributed over all the gear teeth. If such wear does occur, the whole coupling should be replaced.

Special Couplings

Other couplings now used have flexible or resilient materials to compensate for misalignment. The resilient materials in these couplings, rubber, steel, brass or leather, transmit the power from one coupling half to the other and compensate for misalignment by their own deformation. Such couplings should be maintained in proper position at all times so that

when there is a misalignment the reactionary stresses, set up by the force needed to deform the resilient material, will not be too great. Couplings with resilient members are used where it is reasonable to expect very little misalignment. Wherever this type of unit is used, the alignment of the installation should be checked periodically. Fluid couplings are used in coupling applications where the loss of motion is not detrimental to the overall action.

The size of a flexible coupling should be carefully considered so that it will operate satisfactorily and be economical. All coupling manufacturers have simple sizing charts to aid in the selection of the various types of couplings. The usual error is to pick a coupling too small for the peak load to be carried.

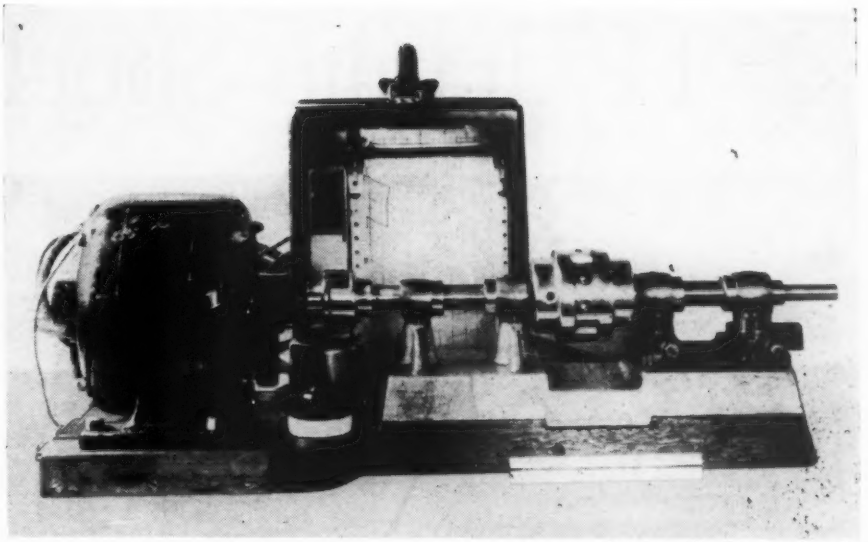
Flexible couplings are frequently adapted to combine several functions. These combinations often result in lower overall costs and make possible installations in a limited space. A coupling is sometimes constructed with one oversized member to form an integral brake wheel. The brake wheel can be of various diameters and widths for any given coupling size. Bar holes can be drilled in one of the coupling members where it is necessary to periodically rotate the machines by hand.

Shear pin couplings are made with a shaft sleeve engaging the coupling through pins designed to shear at a predetermined maximum torque. This type of coupling adds an extra factor of safety without requiring an appreciable amount of space.

Where long shafts connect two pieces of equipment, a tendem coupling is often used. A tandem coupling multiplies the amount of misalignment that can be compensated, and eliminates the need for outboard bearings.

A standard gear-type coupling can be equipped with a thrust plate to carry end thrust from one of the connected shafts without impairing its effectiveness as a flexible coupling. Another coupling modification provides for endwise adjustment of the shaft without relocating the coupling.

The minor modifications that can be made to standard couplings are almost numberless. Each installation is liable to introduce different needs. In all applications, however, the design should embody the basic requirements of good coupling design. The couplings should be large enough to carry the power of the machines, and should be designed to provide maximum protection against any misalignment that might occur in the system.



American Flexible Coupling Co

Fig. 1—A typical stand, with adjustable bearing mounts, used for testing flexible couplings in misalignment. Power input to motor is measured by recording wattmeter seen in back.

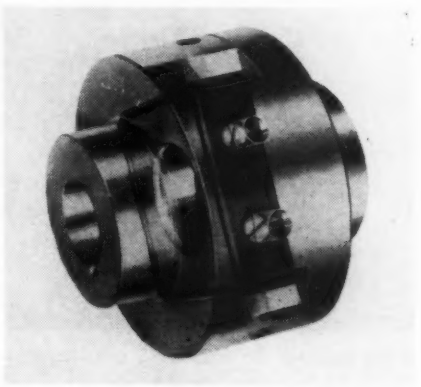


Fig. 2—An Oldham-type coupling with replaceable bearing strip, secured by screws.

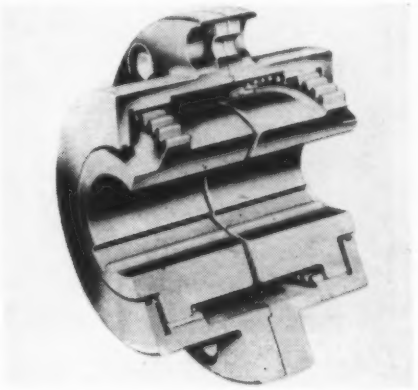


Fig. 3—A gear-type flexible coupling, showing shaft hubs and connecting sleeve.

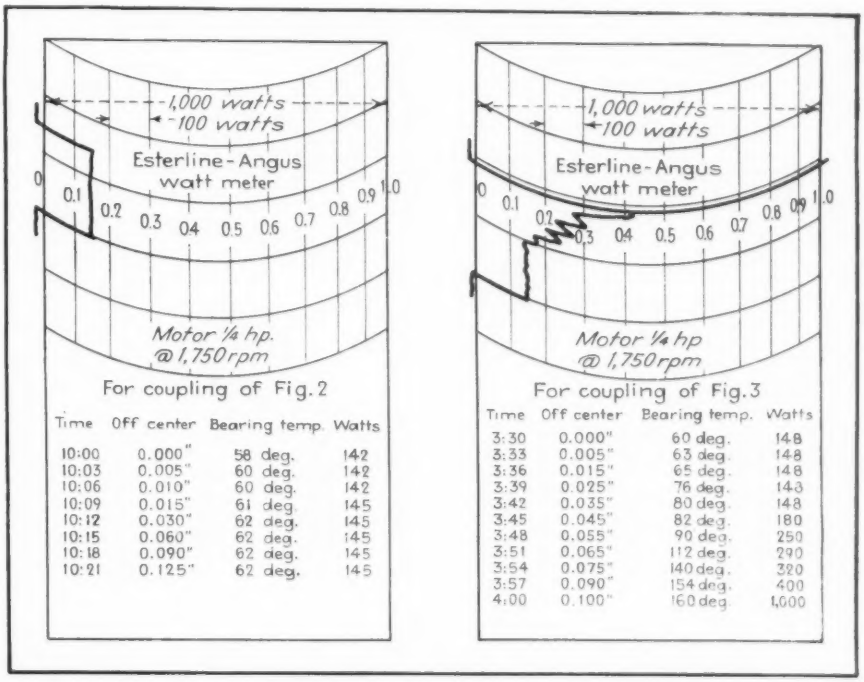
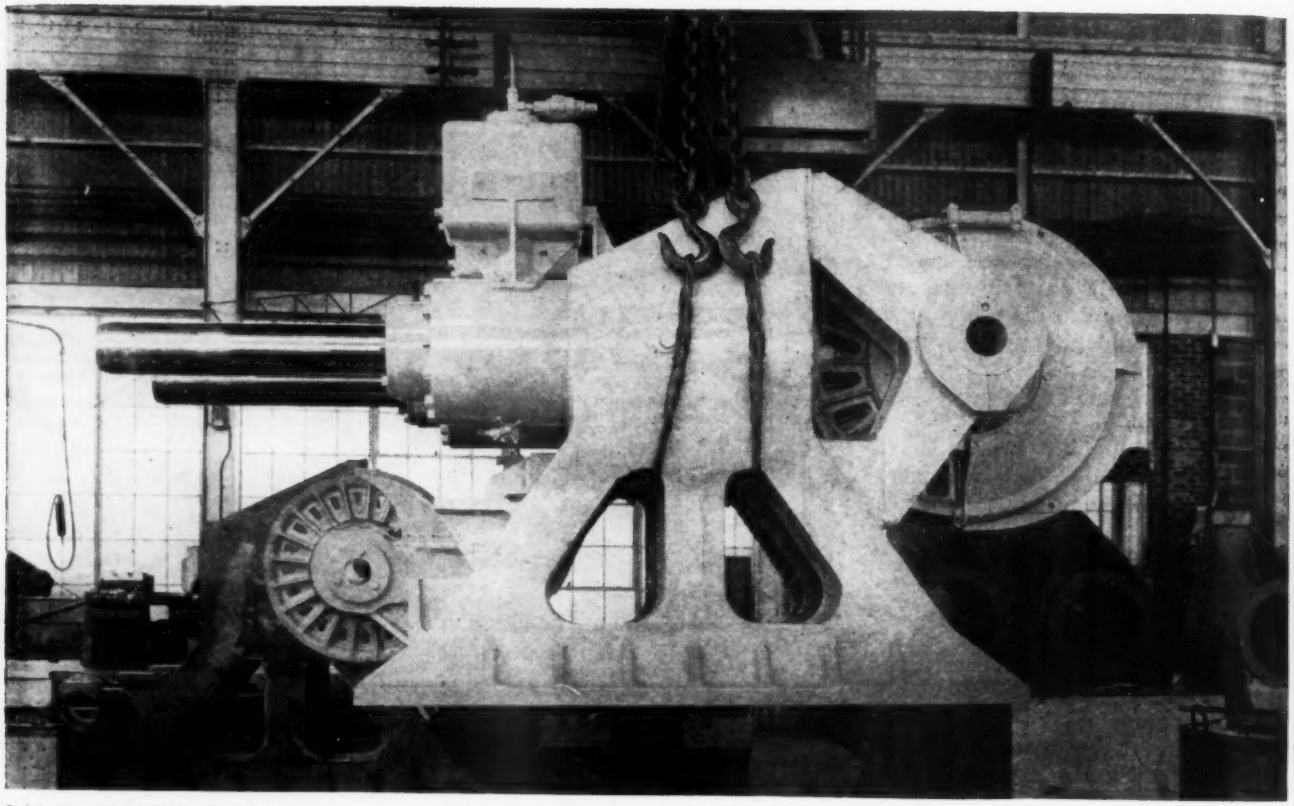


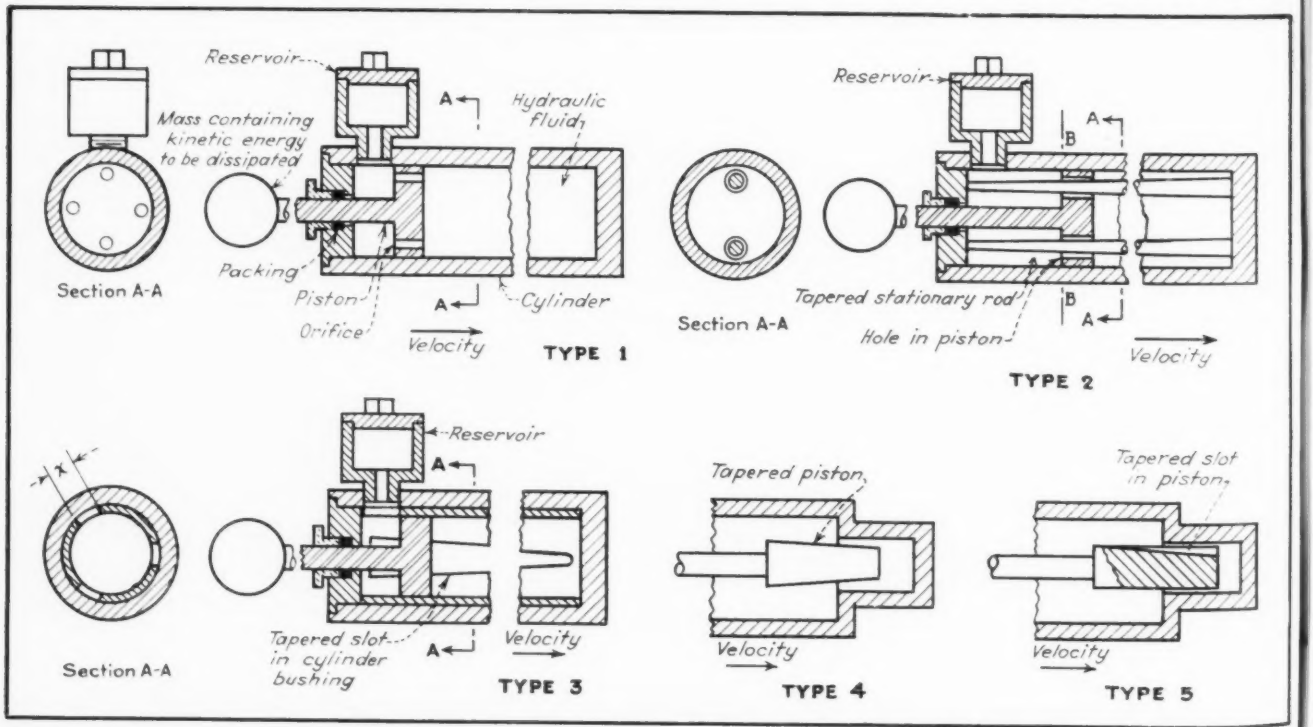
Fig. 4—Charts showing power input to motor when movable bearings were adjusted to give misalignment of varying amounts to both Oldham and gear-type flexible couplings.

Hydraulic Shock Absorber



LARGE CROSSHEAD BUFFER for an aircraft catapult for shipboard installation. Careful orifice design reduces size of equipment.

Orifice Area Variation With Piston Stroke Sets



1 Five orifices. Type 1—non-uniform deceleration. Type 2—uniform deceleration. Types 3, 4 and 5—near-uniform deceleration. Rated for ease of manufacture, Type 1 is best, followed by Types 3, 4 and 5. Type 2 requires careful profiling of tapered pins.

Orifice Designs and Equations

Derivation of useful equations for the design of orifices for hydraulic shock absorbers, buffers and dashpots. Five orifice types are discussed and methods for obtaining values for transient pressures and velocities are explained.

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Engineer, Naval Aircraft Factory

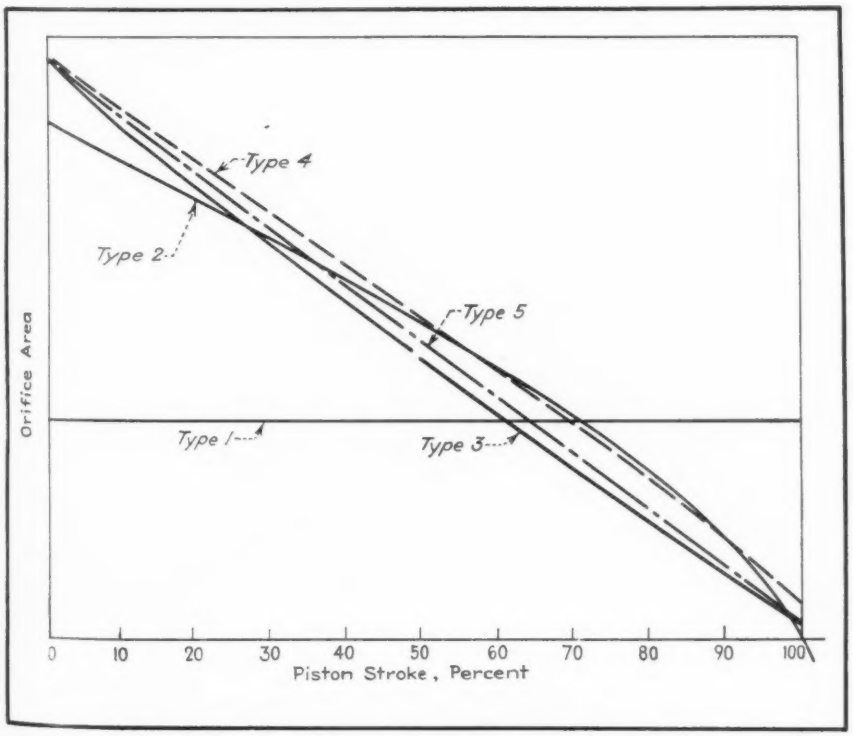
The orifice design equations derived in this article are used at the Naval Aircraft Factory. Much of the data given is from a thesis Mr. Brown presented to the Towne Scientific School of the University of Pennsylvania.

HYDRAULIC SHOCK ABSORBER ORIFICES may be satisfactorily designed by using the equations derived in the following discussion. These equations have the advantage over usual methods for selecting orifice configurations because they allow the designer to avoid tedious calculations. Also the formulas give more accurate results than those of the cut and try school.

Hydraulic shock absorbers are commonly used for absorbing and dissipating undesirable kinetic energy. Other devices, such as springs or compressed air, store kinetic energy, but do not dissipate it. Hydraulic shock absorbers are used for dashpots, automobile wheel shock absorbers, airplane landing gear struts, recoil mechanisms on large caliber guns, and for many other applications. The usual hydraulic shock absorber mechanism is a piston sliding in a cylinder filled with a low viscosity liquid. As the liquid flows past the piston through orifices provided for the purpose, the kinetic energy of the body attached to the piston is transferred to the liquid, thus bringing the piston to rest.

Typical shock absorbers are shown in Fig. 1. The piston is connected directly to the mass. It is also possible to make this connection through a motion-reducing linkage. As shown in the diagram, the piston rod is in compression. This is preferable to putting the rod in tension, because the rod packing is on the low presure side of the cylinder, thereby reducing friction and leakage. The reservoir shown in the diagram is large enough to hold the fluid displaced by the piston rod.

Performance of Shock Absorber



2 Approximate variation of orifice area vs. piston stroke for five orifice types. Note that orifice area at end of stroke is zero for Type 2 orifice only.

The first orifice shown in Fig. 1 is known as a constant-area orifice and is referred to as type 1 in this discussion. These orifices have the same cross-sectional area for the entire stroke of the piston.

Constant-area orifices are employed in light installations such as dashpots and bumpers where ease and cheapness of construction are more important than weight or precise control of transient pressures and decelerations.

For heavy recoil cylinders, orifices are designed to effect constant- or near-constant deceleration. They are used when weight saving is important and cost is not. Applications are to be found in large caliber guns and other heavy machinery.

Constant- or near-constant deceleration orifices are constructed in a number of different ways. One type of constant deceleration orifice is shown as Type 2. Variation in orifice area is obtained by the action of the stationary tapered rods in passing through the piston head. The orifice cross-section for any position of the piston rod is the difference between the net area of the piston head passages and the net area of the tapered rods at section B-B.

Several near-constant deceleration orifices are shown as Types 3, 4 and 5. In Type 3, the orifice is obtained by grooving the cylinder wall as shown. The depth of the groove is constant and the chord varies linearly with piston stroke. Frequently, instead of cutting the grooves in the cylinder wall, the same effect is obtained by inserting a slotted bushing in the cylinder; this method has the advantages of ease of construction and greater facility in providing a suitable bearing surface for the piston.

The orifice shown as Type 4 is created by the action of the tapered piston head in moving into the stepped-down portion of the cylinder. It is easier to manufacture than type 3.

For Type 5, the orifice is produced either by cutting slots of constant width and uniformly tapered depth in the piston head or by cutting bush-

ing slots whose edges form a helix in the bushing.

Orifices of types 3, 4 and 5 are compromise designs between types 1 and 2. They are used if near-constant deceleration characteristics are required and are not quite as costly to manufacture as type 2 where the pins must be cut with a non-uniform taper. The approximate variation of orifice areas with piston stroke for all five types is shown in Fig. 2.

Other orifice forms can be designed, but they will be variations or combinations of the five types shown. There are also many variations in dashpot mechanisms, but the orifice principles remain the same, regardless of linkages or other artifices. A cut away of an actual cross head buffer equipped with a Type 3 orifice is shown in Fig. 3.

Deriviation of Equations

The following symbols are used:

a	= total orifice area, in.²
A	= piston area, in.²
c	= orifice discharge coefficient,
d_c	= diameter cylinder, in.
D	= piston diameter, in.
D_o	= piston dia at start of travel, in.
E	= energy absorbed by fluid, ft lb
f	= acceleration, ft/sec²
F	= force on piston, lbs
g	= acceleration of gravity, 32.2 ft/sec²
p	= pressure, lb/in.²
s	= piston travel from start, in.
s_{max}	= full stroke of piston, in.
v	= velocity of piston, ft/sec
V	= velocity of fluid, ft/sec
W	= weight of body to be slowed, lb
γ	= density of fluid in cylinder, lb/ft³

The minor effects of mechanical and fluid friction, weights of moving parts, spring forces, and fluid elasticity are neglected in the following derivations of orifice design formulas. In a later article on the application of orifice formulas, the effect of these quantities will be taken up.

By Bernoulli's theorem

$$\frac{144p}{\gamma} = \frac{c^2V^2}{2g} \text{ or } p = \frac{c^2V^2\gamma}{2g \times 144}$$

Hence, force on piston is

$$F = Ap = \gamma c^2V^2A/(288g)$$

Work done by piston during stroke is

$$E = \int_o^s Fds/12$$

This equals the change in kinetic energy of the mass to be stopped.

Hence

$$W(v_o^2 - v^2)/2g = \int_o^s \gamma c^2V^2Ads/(3456g)$$

By the continuity equation

$$V = Av/a$$

Therefore where v_o = velocity of weight W at start of stroke

$$W(v_o^2 - v^2)/2g = \int_o^s \gamma c^2v^2A^2ds/(3456ga^2)$$

Differentiating and dividing through by v^2

$$-W\,dv/v = \gamma c^2A^2ds/(3456a^2) \qquad (1)$$

Also we have from above

$$p = \gamma c^2A^2v^2/(288ga^2) \qquad (2)$$

Type 1 Orifice

Here the orifice area is constant. Integrating Eq (1)

$$\log \frac{v_o}{v} = \frac{\gamma c^2A^2s}{3456\,a^2W} \qquad (3)$$

In the foregoing equation, if v is set equal to zero, it will be seen that s is infinite. Theoretically then it is impossible to bring the weight to a complete stop. However, v can be reduced to an arbitrarily small magnitude. The maximum pressure can be found from Eq (2) by substituting the maximum velocity for v which is, of course, v_o.

Type 2 Orifice

is designed to effect constant deceleration, and the problem is to determine the orifice size variation. Dividing both sides of Eq (1) by dt

$$-\frac{W}{v}\frac{dv}{dt} = \frac{\gamma c^2A^2}{3456\,a^2}\frac{ds}{dt}$$

or, $Wf = \gamma c^2A^2v^2/(288a^2)$

For this type of orifice, f is constant, hence:

$$v^2 = v_o^2 - 2fs/12$$

and $$\frac{288\,a^2fW}{\gamma^2c^2A^2} = v_o^2 - 2fs/12$$

Therefore

$$a^2 = (v_o^2 - 2fs/12)\frac{\gamma^2c^2A^2}{288fW} \qquad (4)$$

from which a may be solved for any point along the travel s. Since f is constant, p is constant and

$$p = F/A = Wf/gA \qquad (5)$$

It is evident that p_{max} will be least for this type of orifice.

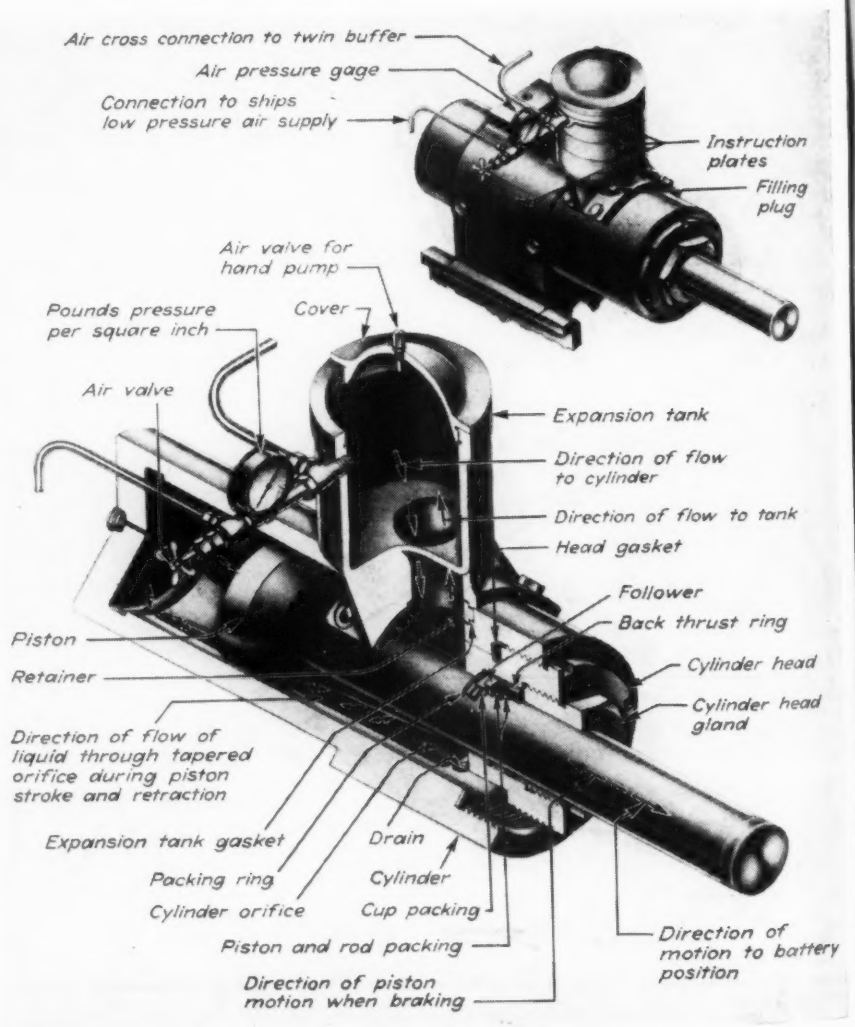


Fig. 3—Cut-away of a cross-head buffer equipped with Type 3 orifice, showing typical design.

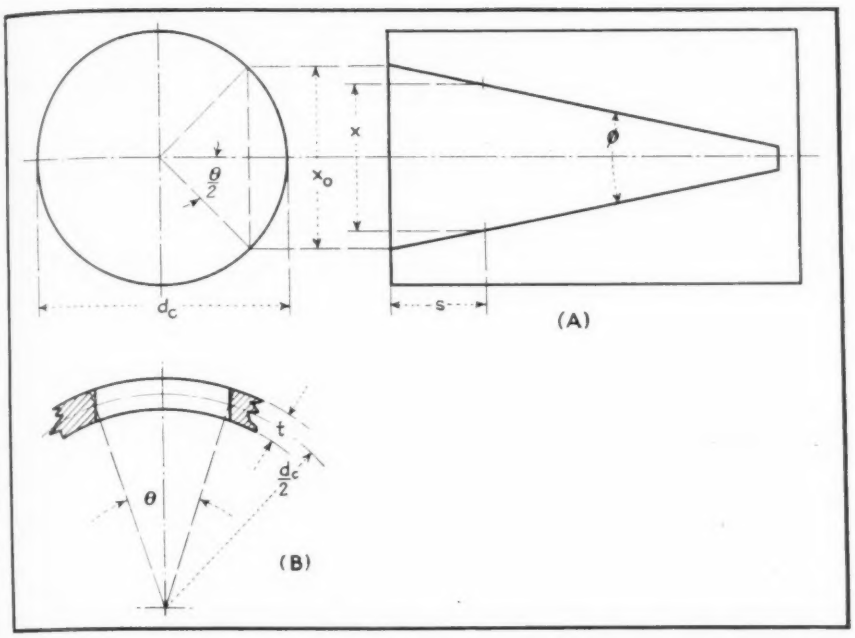


Fig. 4—Geometry of tapered cylinder slot for Type 3 orifice. Slot is easily machined.

TYPE 3 ORIFICE

The usual method of solving for velocity is to divide the stroke into a sufficient number of small segments and compute the pressure over the first segment using Eq (2) and assuming that $v = v_o$ is constant over the whole segment. The deceleration is then computed using Eq (5). The velocity for the next segment is found remembering that $v^2 = v_o^2 - 2fs/12$. This process is repeated until the velocity is found for every segment. The disadvantages of this method are as follows: 1. The fewer the segments taken, the more the point of maximum pressure is moved toward the beginning of the stroke. By integration, the actual point of maximum pressure is found to be nearer the end of the stroke. 2. Any error at the beginning of the calculations will necessitate starting over from the point of error; moreover the error is cumulative; 3. Many times, after all the work of computation is carried out, it will be found that the entire stroke has not been used efficiently, in that v becomes negligible too soon along the stroke (thus introducing higher pressures than are necessary), or that v is too high at the end of travel causing shock absorption to be inadequate. This applies to step-by-step computations carried out for type 4 and 5 orifices also. The following method simplifies the procedure.

If the width of the slot is described by the following expressions [see Fig. 4(*A*) and 4(*B*)].

$(x_o - x)/s = k$ where $\frac{k}{2}$ also equals $\tan(\phi/2)$

and $\sin(\phi/2) = x/d_c = (x_o - ks)/d_c$

$ks = x_o - d_c \sin(\phi/2)$

and $ds = -d_c \cos(\phi/2)d\phi/(2k)$

Also from Fig. 4(*B*),

Let

n = number of slots
t = thickness of slot, in.
θ = angle of slot, radians

Then

$a = d_c\theta tn/2$

Substituting in Eq (1),

$$Wdv/v = \frac{\gamma c^2 A^3 d_c \cos(\theta/2)d\theta}{6912\, k(d_c/2)^2 t^2 n^2 \theta^2}$$

Integrating,

$$W \log_e \frac{v}{vo} = \frac{\gamma c^2 A^3}{13{,}824\, d_c k(tn/2)^2} \times \left[\frac{-\cos(\theta/2)}{(\theta/2)} - \frac{\theta}{2} + \frac{(\theta/2)^3}{3\lfloor 3} - \frac{(\theta/2)^5}{5\lfloor 5} + - + \cdots\right]_{\theta_o}^{\theta} \quad (6)$$

The first two terms of the brackets will normally be a close enough approximation because the series converges very rapidly. The maximum pressure then can be obtained by substituting for v in Eq (2) from Eq (6), differentiating with respect to θ and equating to zero. However, plotting is simpler and more practical.

TYPE 4 ORIFICE is produced by the conical piston sliding through the cylinder entrance. The slope of the piston sides is defined by $D - D_o/(2s) = k$. Also $a = 0.7854\,(d_c^2 - D^2)$ taken at the cylinder entrance. Substituting for a in Eq (1) and noting that $A = 0.7854D^2$,

$$-W\,dv/v = \frac{\gamma c^2}{3456}\left[\frac{(0.7854)^3 D^6 ds}{0.7854^2\,(d_c^2 - D^2)^2}\right] = \frac{0.7854\,\gamma c^2}{3456.}\,\frac{D^6 ds}{(d_c^2 - D^2)^2}$$

but

$2sk + D_0 = D$

then

$ds = dD/(2k)$

Therefore

$$-W\,dv/v = \left[\frac{D^6\,dD}{(d_c^2 - D^2)^2}\right]\frac{\gamma c^2}{8800\,k}$$

Integrating,

$$W \log_e \frac{v_o}{v} = \frac{c^2\gamma}{8800\,k} \times \left[\frac{D^5 + 5d_c^2 D^3 - (15/2)\,d_c^4 D}{3(d_c^2 - D^2)} + \frac{5d_c^3}{4} \log_e \frac{d_c + D}{d_c - D}\right]_{D_o}^{D} \quad (7)$$

v may be solved directly for any D or s for a convenient number of points; the corresponding values of pressure then may be computed using Eq (2) as explained for the type 2 orifice.

TYPE 5 ORIFICE area varies directly with the length of stroke. The variation of orifice area may be expressed as

$a = a_o - ks$ and $ds = -da/k$

Substituting in equation (1)

$-W\,dv/v = \gamma c^2 A^3 ds/(3456\,a^2) = -\gamma c^2 (A - a)^3\,da/(3456a^2k)$

$= -\gamma c^2 (A^3 - 3A^2a + 3Aa^2 - a^3)da/(3456ka^2)$

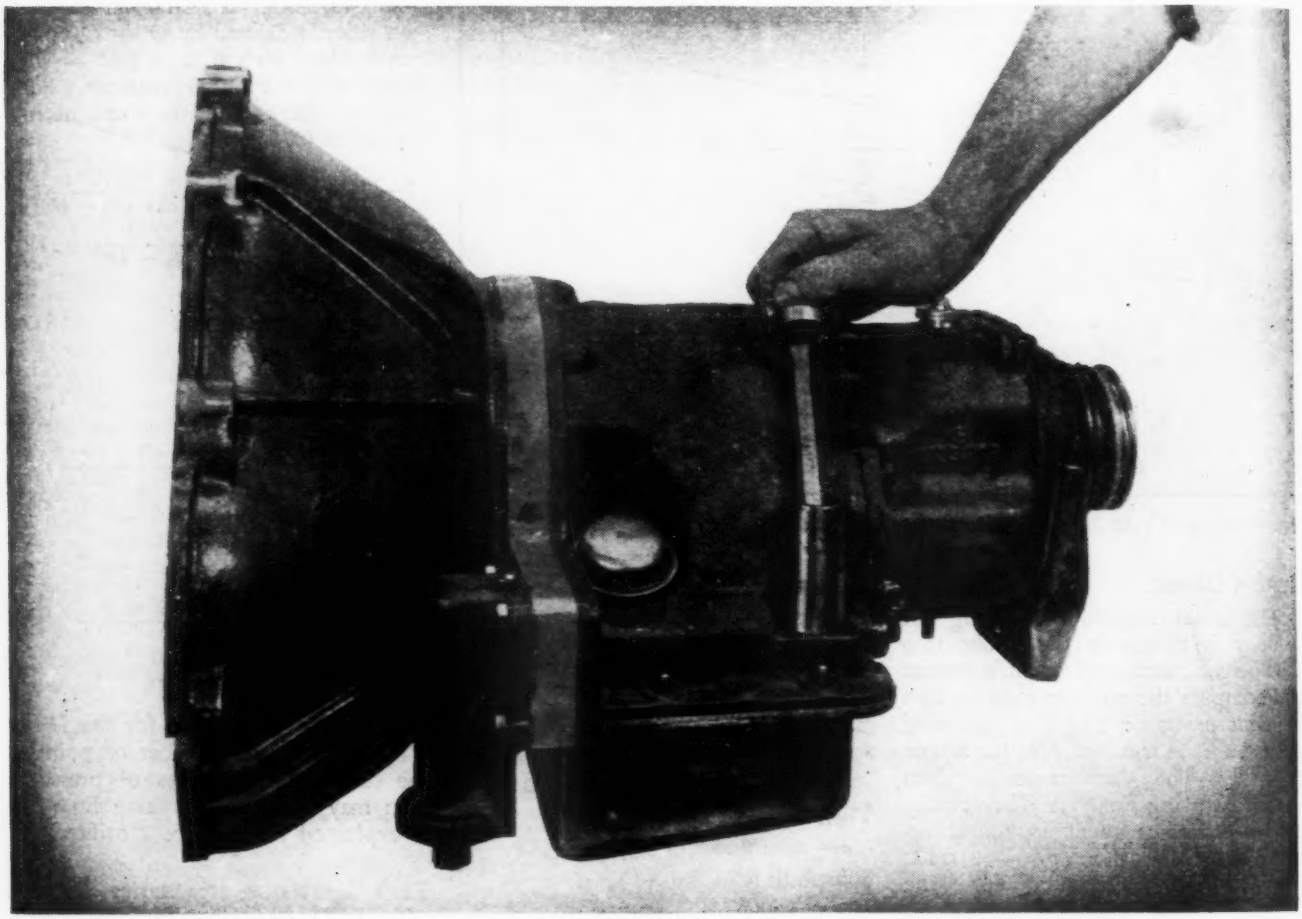
Integrating,

$$W \log_e (v/v_o) = \frac{c^2\gamma}{3456k}\left[-\frac{A^3}{a} - 3A^2 \log_e a + 3Aa - \frac{a^2}{2}\right]_{a_o}^{a} \quad (8)$$

Maximum pressure for this type orifice may again be found as the sections dealing with types 3 and 4 orifices.

* * * *

SINCE 1889, the recognized unit of length has been the distance between two lines scratched on the surface of a platinum-iridium bar reposing in the building of the International Bureau of Weights and Measures, Paris, France. The meter distance between the marking lines was first suggested as a length unit in 1790. It was defined as one ten millionth of the earth's quadrant. Precise measurements are now made by use of light wavelengths from the cadmium red line. The human eye is not too sensitive to red, and the cadmium red line is too wide for accurate measurement, so the green line of mercury isotope 198 is being considered for the ultimate standard of length.

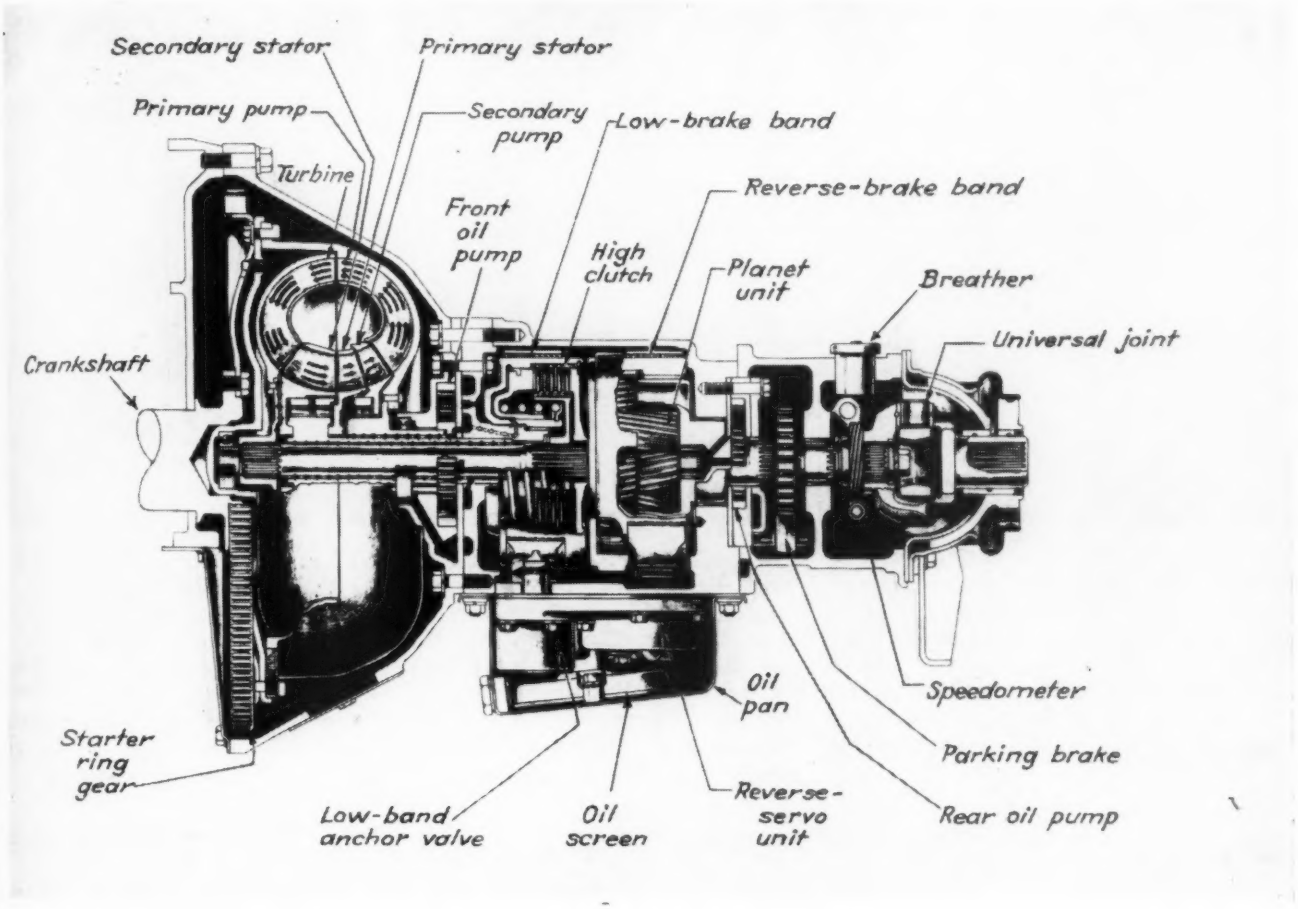


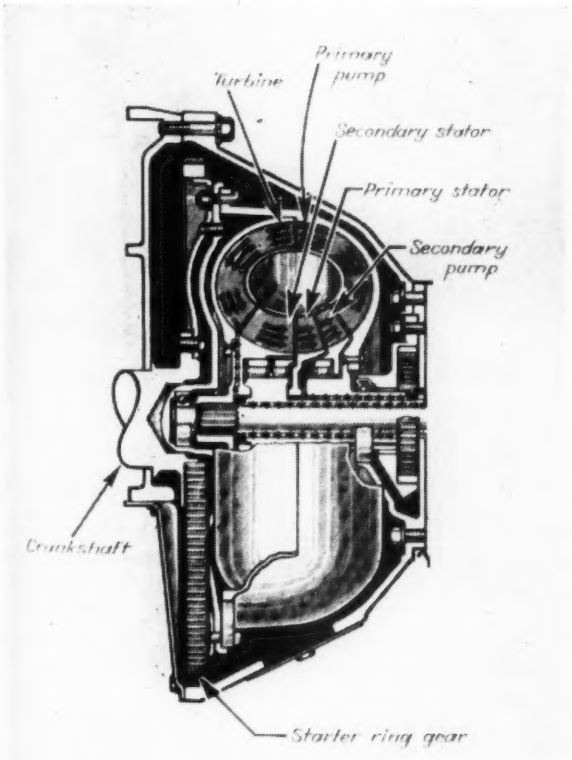
Buick's New Dynaflow Transmission

Free wheeling bladed reaction units added to a hydraulic coupling form the torque converter that is the heart of the 1948 Buick Dynaflow automotive transmission. These free wheeling units give automatic directional control to the oil flow in the converter as it leaves the turbine and enters the pump. Thus the engine torque is automatically multiplied by the torque converter according to the torque requirements of the rear wheels and all normal driving can be done without manual or automatic gear shift controls.

The Dynaflow transmission is controlled by a manual control lever on the steering column that operates a hydraulic shift control valve. There are five positions in the shift quadrant: "park," "neutral," "direct drive," "emergency low" and "reverse." Neutral position is required for safety while starting engine and permits engine idle adjustments. Direct drive is used for all normal driving in forward speeds and connects the torque converter directly to the propeller shaft. Emergency low engages a gear reduction and is used for abnormal driving conditions when encountering heavy loads requiring added acceleration. When shifting from emergency low to direct drive the transition is smooth and positive. The park position brakes the rear wheels and the reverse position changes the direction of rotation of the transmission output shaft. When coasting, the torque converter operates reversely and permits the engine to be used as a braking force. The engine can be started by pushing the car.

Dynaflow transmission unit is approximately 24 in. long overall and mounts to the engine through a 17½ in. dia flange. The unit weighs 217½ lb without oil. It supplants conventional flywheel, clutch and transmission units weighing 170 lb. Eleven quarts of oil are carried in the pump and converter unit. When in operation 8 quarts are used in the converter and 3 quarts are required to operate the hydraulic controls and provide lubrication. Individual converter blade units are aluminum alloy plaster mold castings with finned sections that are 0.015 in. thick at their edges. Transmission housings are iron castings. Oil pan is a sheet metal stamping.

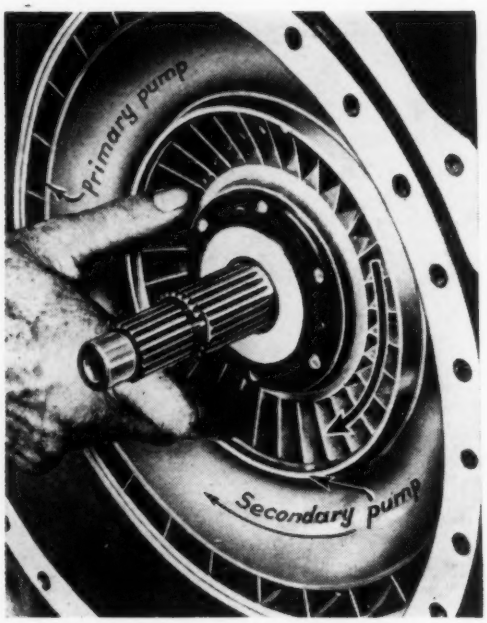




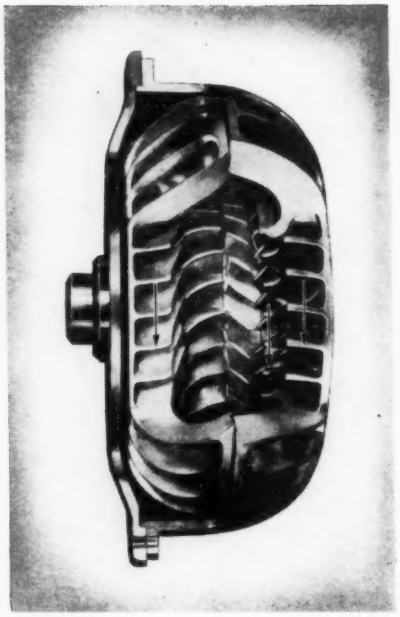
TRANSMISSION COMPONENTS include torque converter, multiple disk direct drive clutch unit and a planetary gear unit. Front transmission pump is driven by the engine and a smaller rear pump by the rear axle through the output shaft. These oil circulating pumps are the internal gear type and supply oil for the torque converter, hydraulic control system and lubrication system. Rear pump is required to operate the direct drive clutch when pushing the car to start the engine. In direct drive over 45 mph it supplies all the necessary oil for the transmission. Parking brake consists of a ratchet wheel splined to the axle shaft and a pawl anchored to the transmission case. When the shift control lever is shifted to the "park" position the pawl mechanically engages the ratchet wheel thus braking the rear wheels.

TORQUE CONVERTER consists of a primary pump, secondary pump, two stators and the driven turbine unit. The primary pump is bolted to the flywheel and turns at engine crankshaft speed. The secondary pump is mounted on a free wheeling clutch on the primary pump hub. The two stators are each mounted on free wheeling clutches that are attached to the stationary reaction shaft.

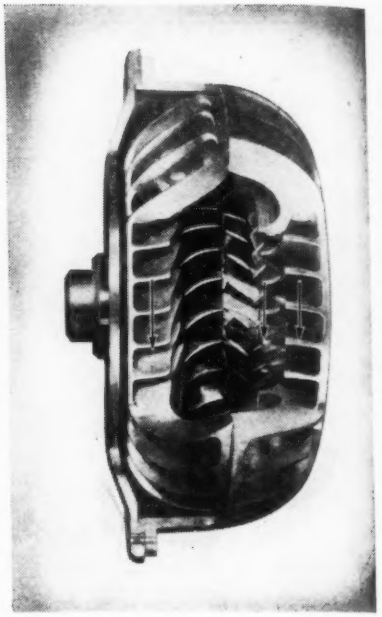
(continued on next page)



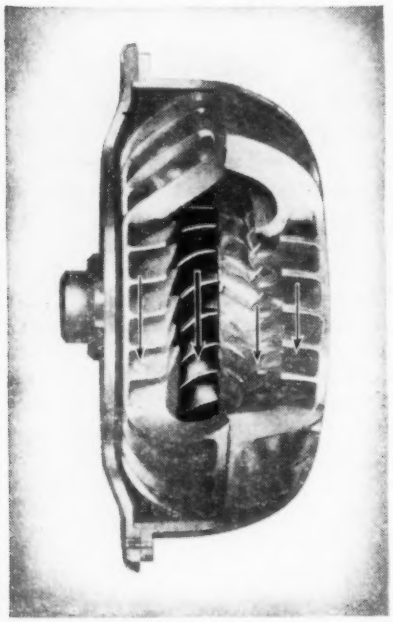
SECONDARY PUMP OVERRUNS the primary pump in the first stage when starting the vehicle or when accelerating or encountering heavy loads. By permitting the secondary pump to overrun, the excessive turbulence and subsequent efficiency drop that would occur if the high velocity oil struck the back of the vanes on the secondary pump is avoided.



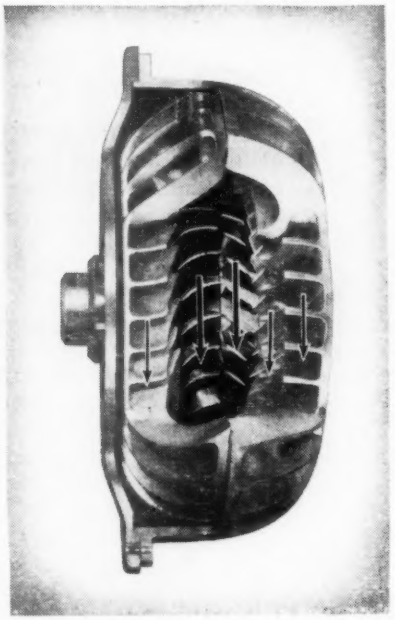
SECONDARY PUMP TURNS with the primary pump in the second stage of operation when oil flow velocity is reduced and the oil no longer impinges in the back of the secondary pump vanes. The transfer between the first and second stage of operation takes place gradually as the load changes.



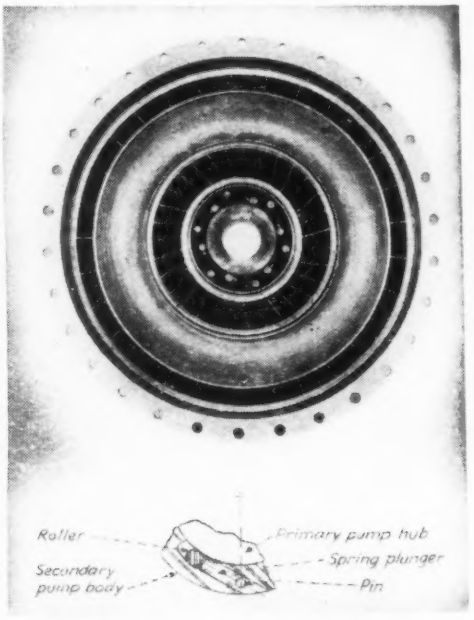
STATORS ARE HELD STATIONARY in first stage of operation when starting the vehicle. This is done so that the stators can absorb large reaction forces to exert directional control of oil flow between pump and turbine when high torque multiplication is required to accelerate the vehicle.



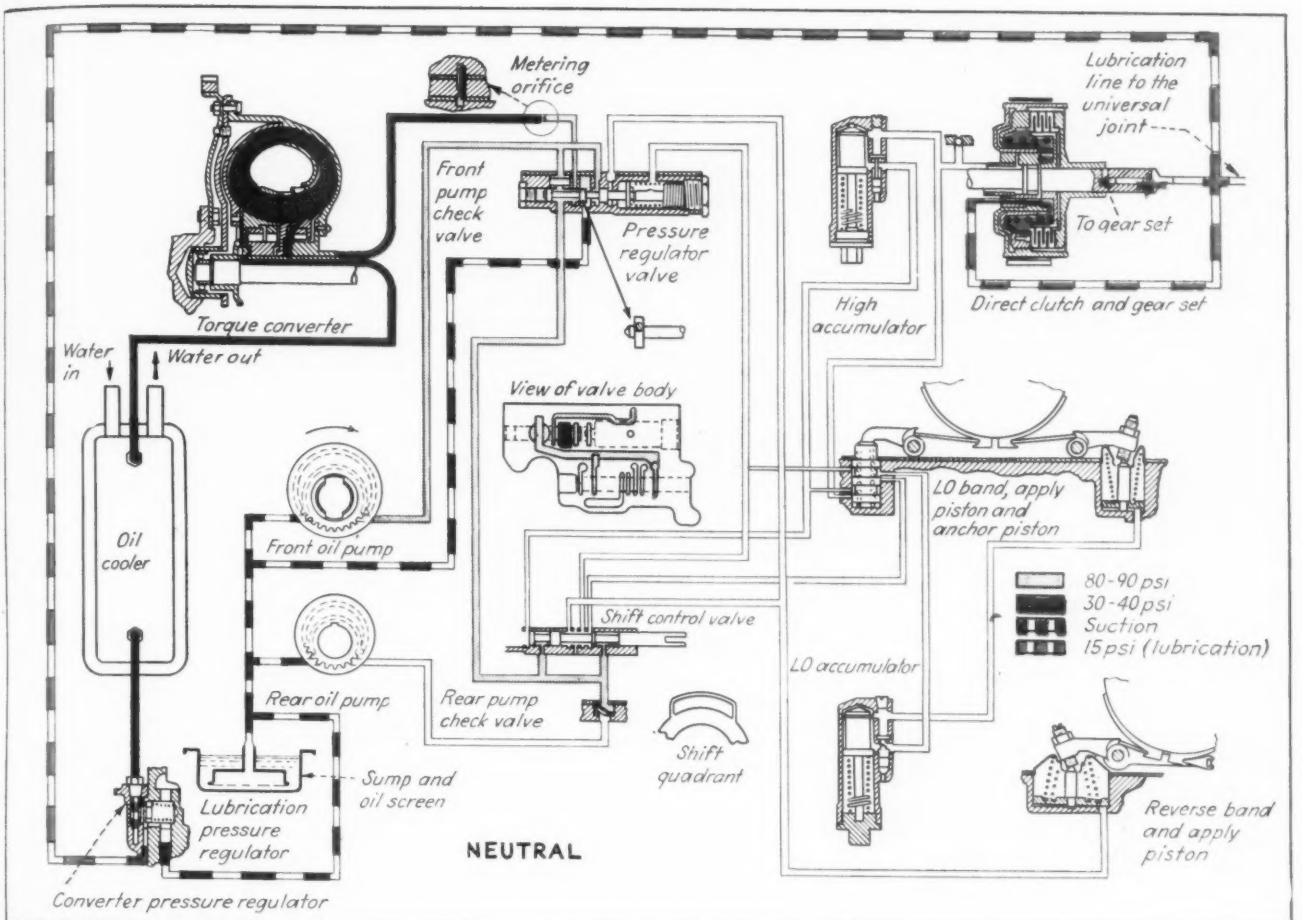
SECONDARY STATOR begins to turn with the pump as the turbine picks up speed. Since the reaction force is thus decreased, a condition is reached when the secondary stator no longer carries any load. The secondary stator is then carried with the rotating oil mass and free wheels.

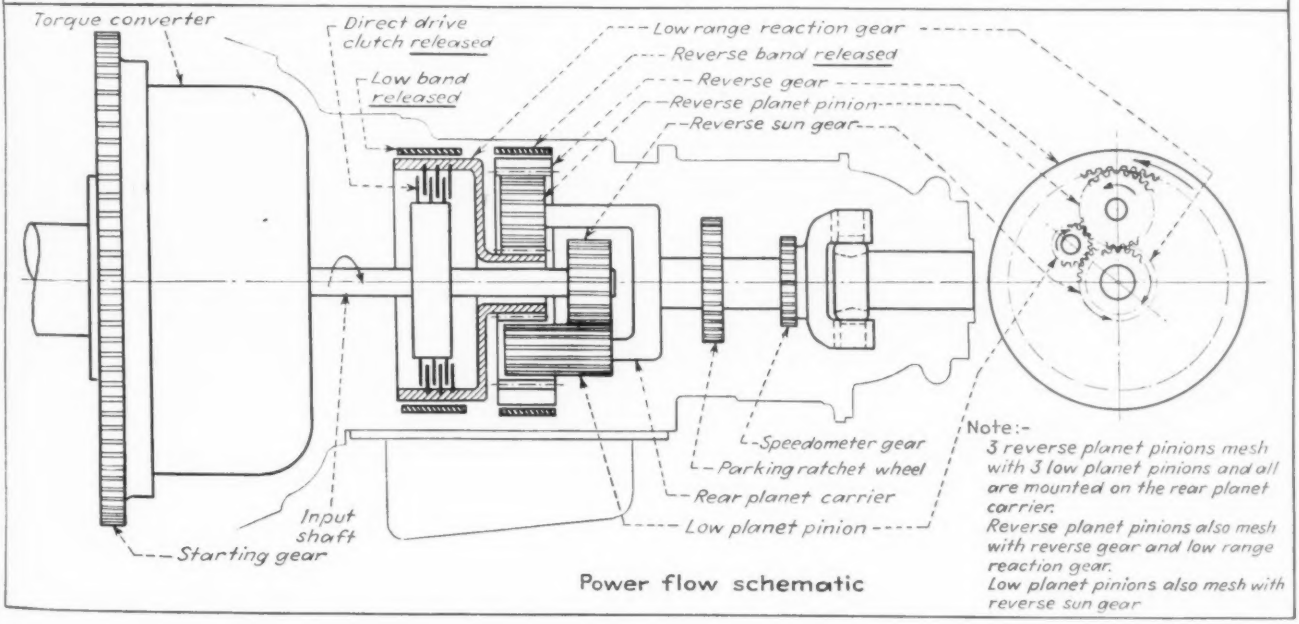


PRIMARY AND SECONDARY STATORS turn with the pump as the turbine approaches the speed of the pump. The torque multiplication requirements are reduced and there is no reaction force against the stators. The converter functions as a fluid coupling between the rear wheels and engine.



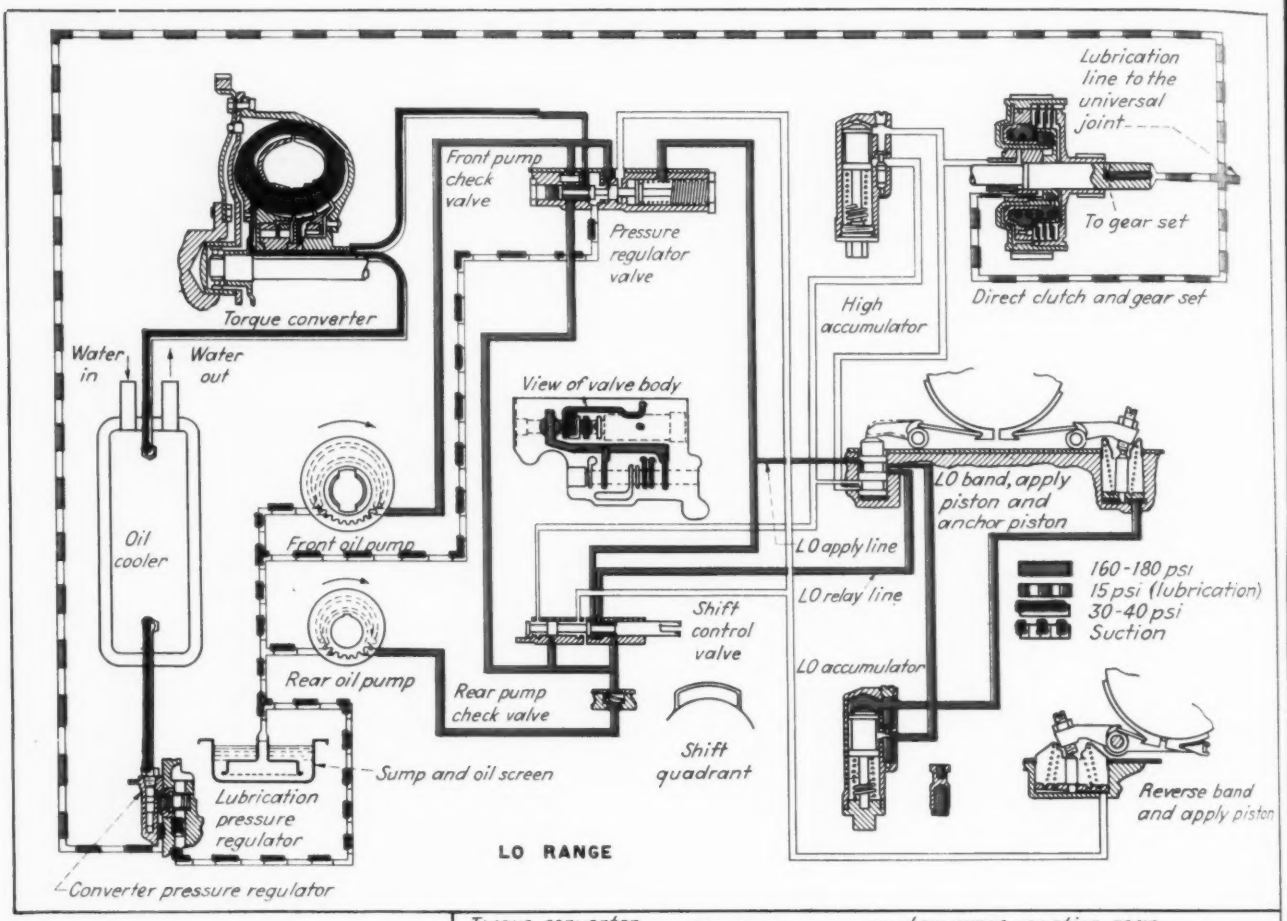
FREE WHEELING of the secondary pump and two stators is accomplished by mounting the individual units on their respective shafts with overrunning clutches. When the individual units are turned in one direction, six rollers are wedged in a tapered path and lock the units to the shafts. In the opposite direction, the rollers are in the clear and the units can rotate freely.

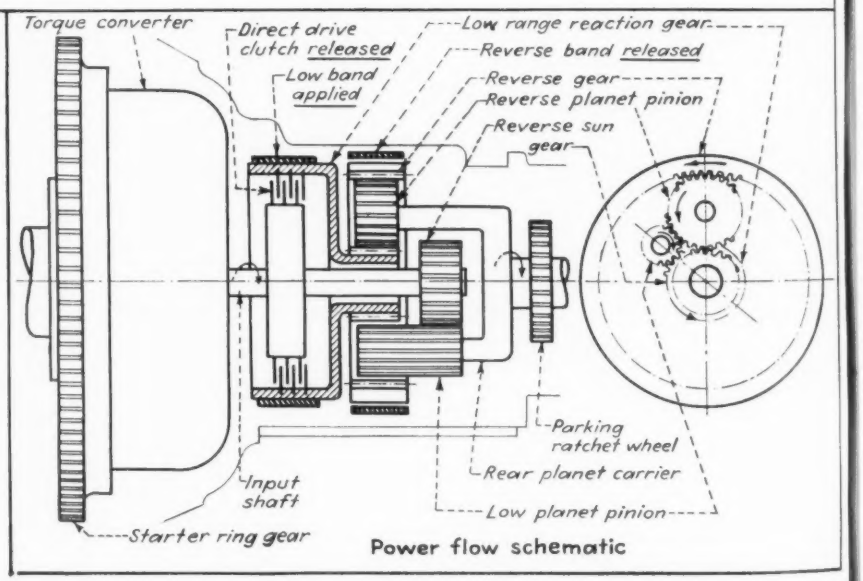



Torque converter
Direct drive clutch released
Low band released
Low range reaction gear
Reverse band released
Reverse gear
Reverse planet pinion
Reverse sun gear
Speedometer gear
Parking ratchet wheel
Rear planet carrier
Low planet pinion
Input shaft
Starting gear
Note:-
3 reverse planet pinions mesh with 3 low planet pinions and all are mounted on the rear planet carrier.
Reverse planet pinions also mesh with reverse gear and low range reaction gear.
Low planet pinions also mesh with reverse sun gear

Power flow schematic

IN NEUTRAL POSITION the planet carrier is stationary. Direct drive clutch, low and reverse bands are released. All gears rotate on their individual axes. A neutral safety switch permits engagement of the starter only when the shift lever is in neutral or park position. Hydraulic control circuit shows the oil flow and pressure conditions when the shift control is in neutral position. Oil is blocked from entering the pressure lines to either of the servo pistons or the direct drive clutch. The front pump supplies oil for the torque converter and lubrication for the direct drive clutch and planetary gear set. The restricted metering orifice and the converter pressure valve are designed to maintain a pressure of 35 to 40 psi in the converter. Lubrication pressure regulator is set for 15 psi. Engine cooling water is circulated through the oil cooler.

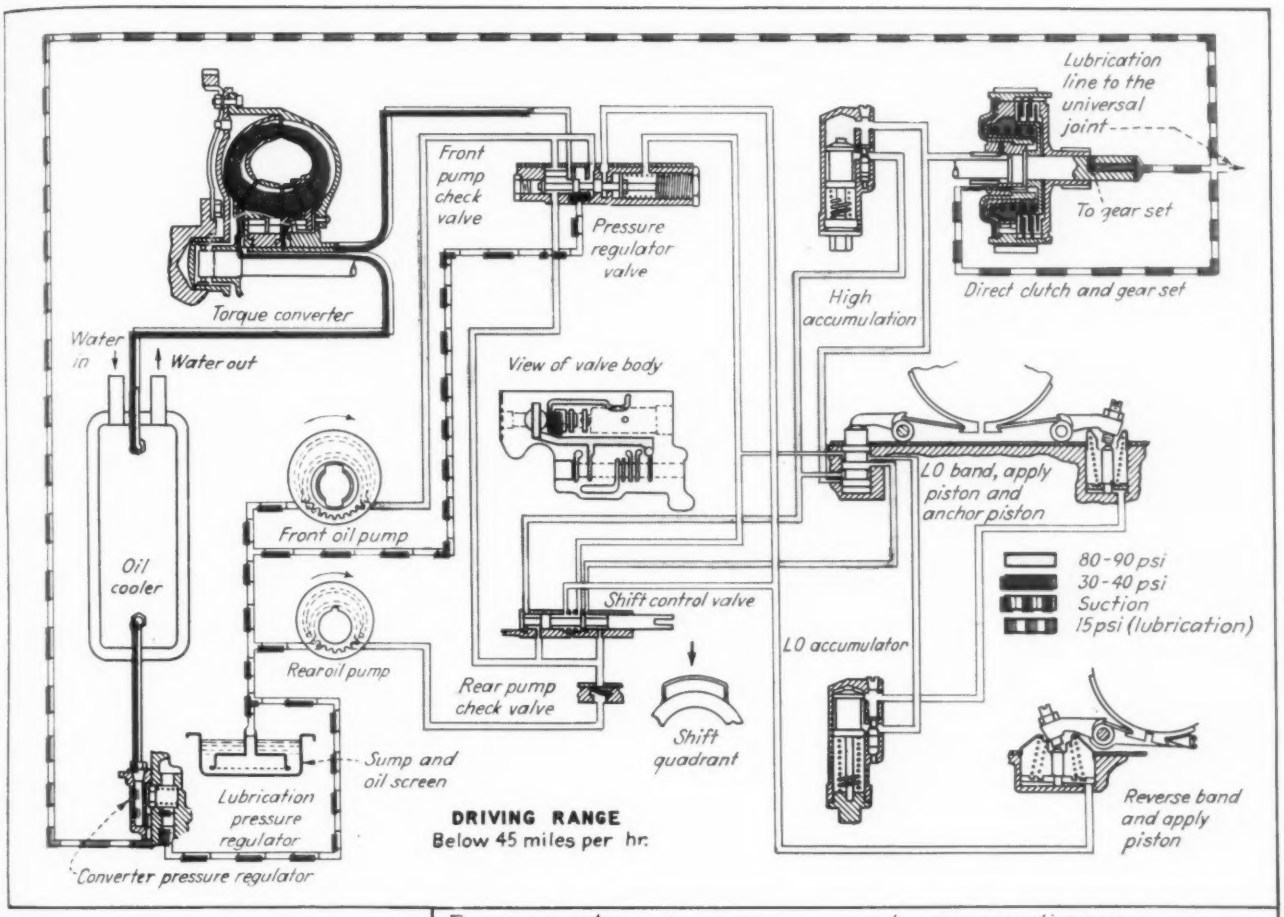


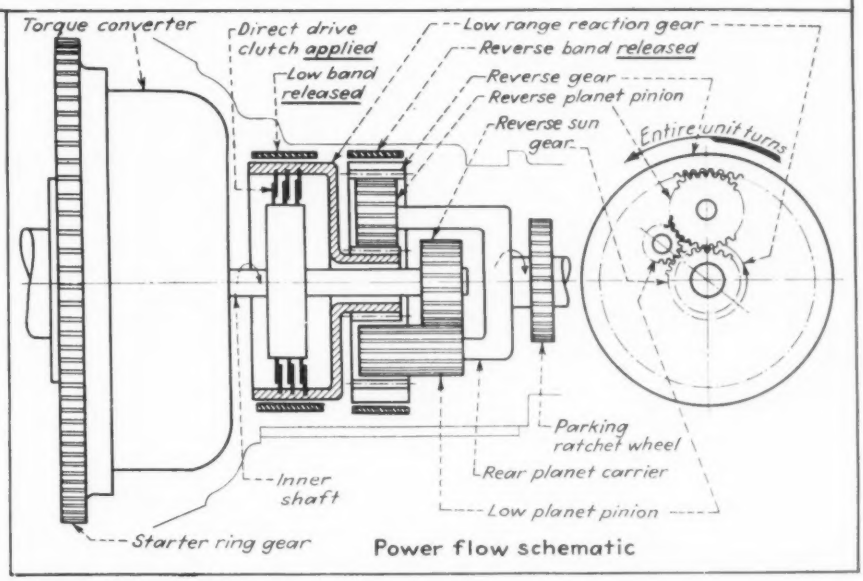


IN EMERGENCY LOW, the low band is applied to the low range reaction gear and holds it stationary. Both direct drive clutch and reverse bands are released. The power flow is from the input shaft through the planetary reduction to the rear planet carrier. This connection introduces a gear reduction of 1.82 to 1 in the driving system. The combination of this gear reduction and the torque multiplication in the converter gives an equivalent gear reduction of approximately 4.1 to 1 at the propeller shaft.

Oil pressure is increased to 180 psi to operate the low brake band. Oil pressure from the front pump is directed to the low servo piston and also to one of the boost chambers in the pressure regulator valve. The addition of oil pressure to spring pressure raises the pressure from 90 psi to 180 psi. An accumulator in the apply line gives rapid, smooth engagement of the band by permitting a large flow of oil up to the point of band application and reduces the flow during application. As the vehicle begins to pick up speed the rear pump also begins to supply oil to the system. The low relay line is included to provide an alternate oil supply to the low servo during movement of the anchor valve.

At the moment of shifting, oil flows through the low apply line to the servo. Oil pressure is also admitted under the anchor piston, and supplements the spring pressure. As oil pressure builds up and locks the low band, the reaction force on the band moves the anchor piston against the spring and oil pressure forces and cuts off the low apply line and opens the low relay line, which continues to apply pressure to the low servo. Check valves in pump pressure lines prevent either working pump from bleeding into idling pump. The final condition in low range as the vehicle starts to move is illustrated.

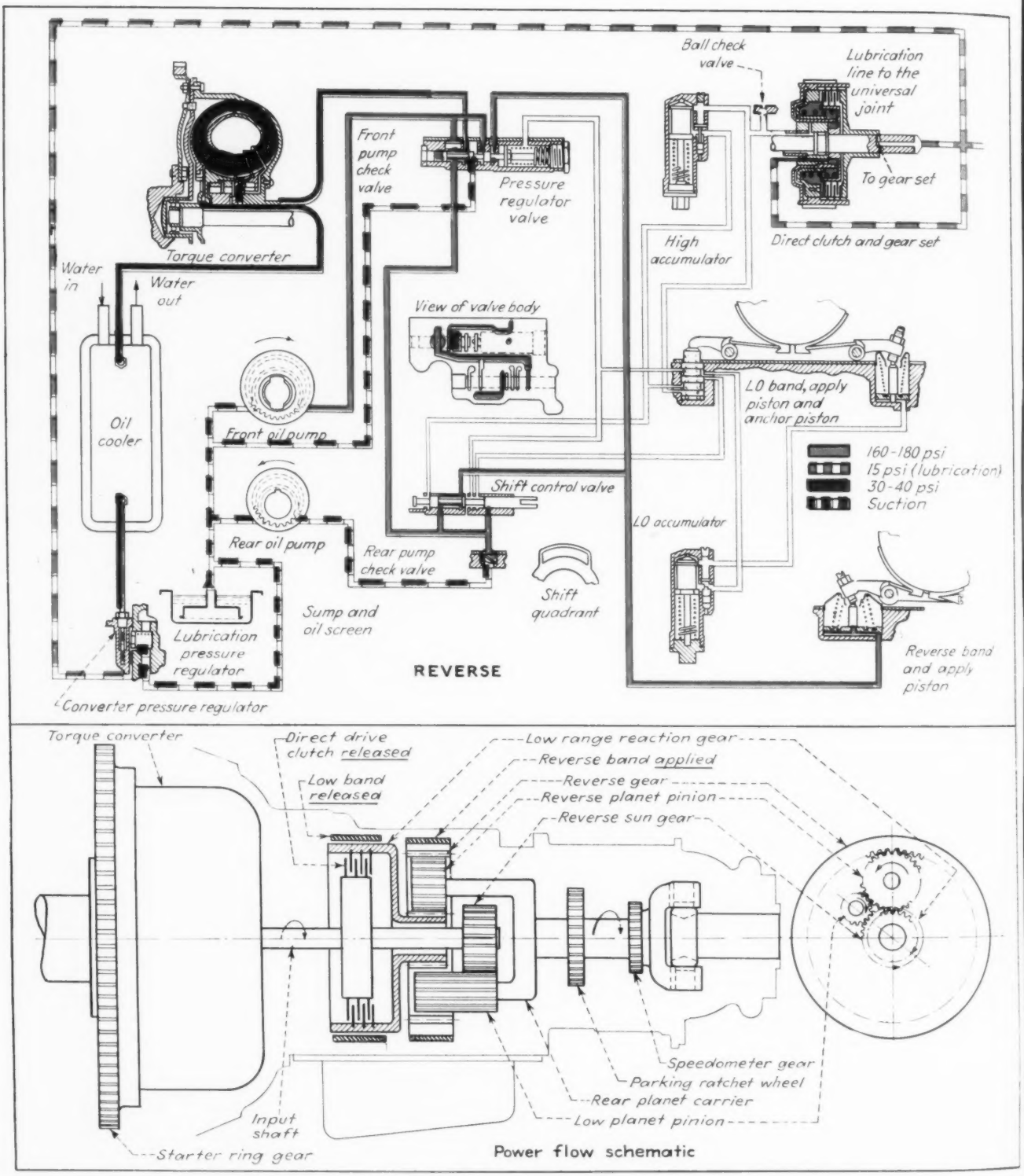




IN DIRECT DRIVE the output shaft and input shaft are locked together. This is the normal connection for all ordinary forward driving conditions and takes full advantage of the torque convertor by using no shift or clutch controls. This locked condition is accomplished by applying the direct drive clutch, which locks the low range reaction gear to the input shaft. The gears in the planetary unit do not rotate and the entire assembly turns as a unit.

Hydraulic circuit shows the pressure conditions in the driving range under 45 mph. An accumulator in the clutch apply line is used for the same purpose as the low accumulator and serves to engage the multiple disk clutch smoothly. When it is necessary to shift from low to direct drive the low band is released and the direct drive clutch applied gradually as follows: When the control lever is moved from low to direct drive, the shift control valve, through the low relay line, still maintains pressure in the low servo. At the same time, pressure is directed to the clutch apply line through the low band anchor valve. This oil line bypasses the direct drive accumulator. When the clutch begins to engage, it starts to rotate the low range drum in the opposite direction to the reaction force which held the anchor valve. The spring and oil pressure forces under the anchor valve move it to the position shown. The low servo line is connected to the low apply line, which is open to the sump, and thus all pressure on the band is released.

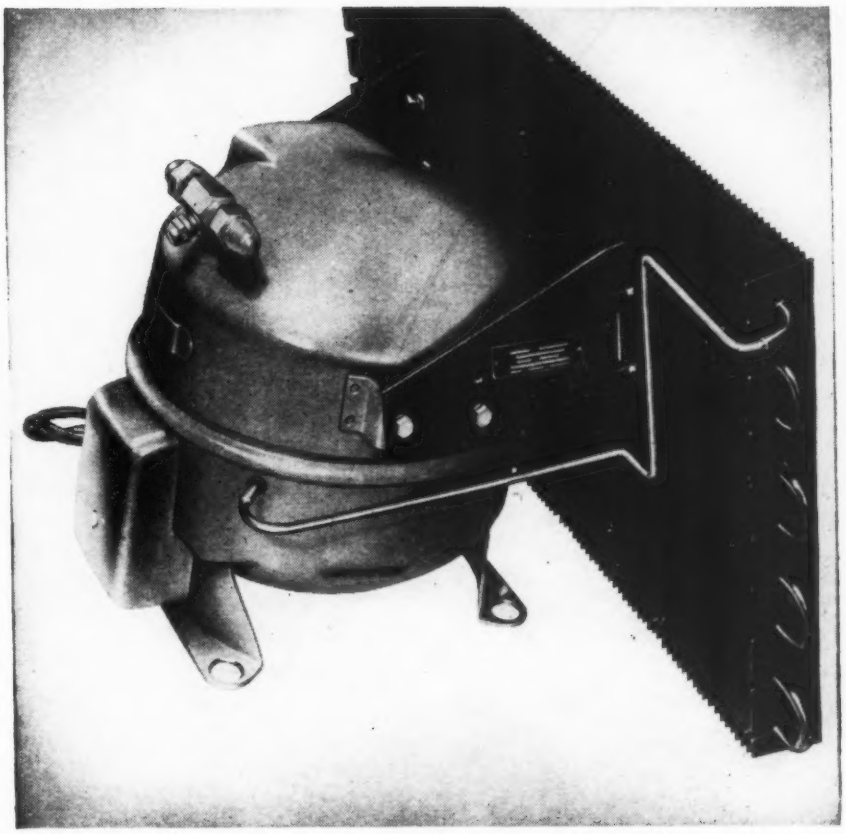
Above 45 mph added efficiency is gained by permitting the smaller rear pump to supply all the oil to the transmission. This occurs when pressure from the rear pump is greater than 90 psi, which causes the front pump check valve to close and oil from front pump flows to sump.



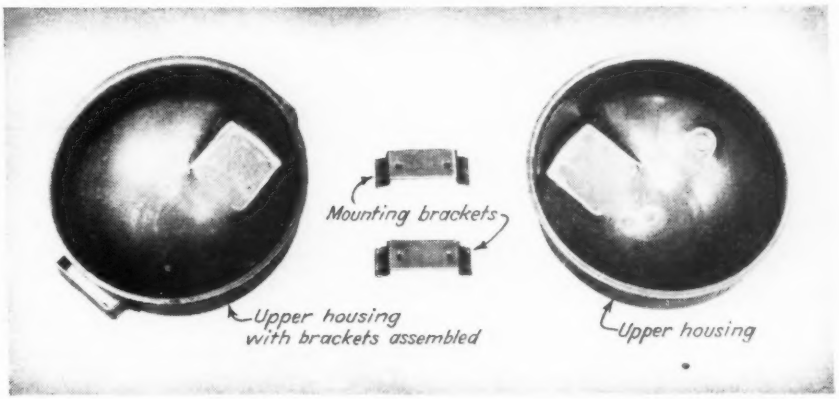
IN REVERSE, the reverse drum band is applied and the low band and direct drive clutch are released. Power is applied through the input shaft and the driving sun gear, which travel in the same direction. The planet carrier and output shaft thus travel in the opposite direction. A gear reduction of 1.82 to 1 is introduced by this combination.

Oil pressure of 180 psi is required to operate the reverse band. Oil pressure is directed to the reverse servo piston and the second boost chamber in the pressure regulator valve. In contrast to the low band design, the reverse band anchor is solidly attached to the transmission case. In both reverse and neutral, the low range drum and the direct drive clutch piston revolve at higher speeds than the input shaft. To stop the centrifugal force of the oil in the clutch apply chamber from partially engaging the clutch, a ball check and vent are included in the system. They prevent this action by letting oil drain from the apply chamber. Suction during draining is prevented by venting the clutch pressure line.

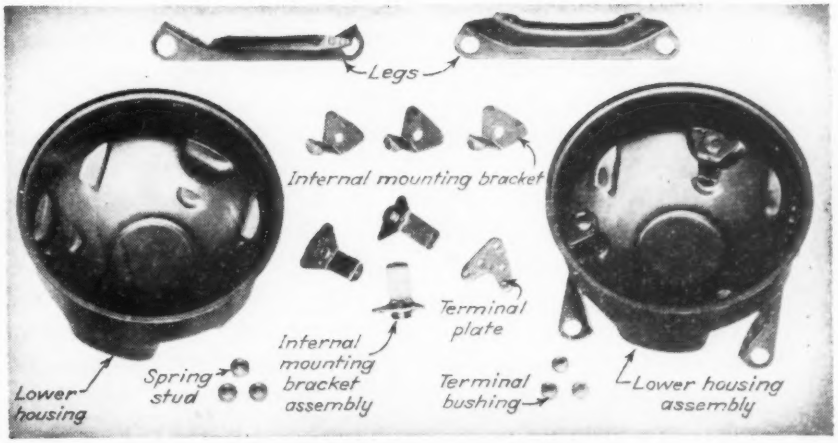
All Sheet Metal Compressor Housing



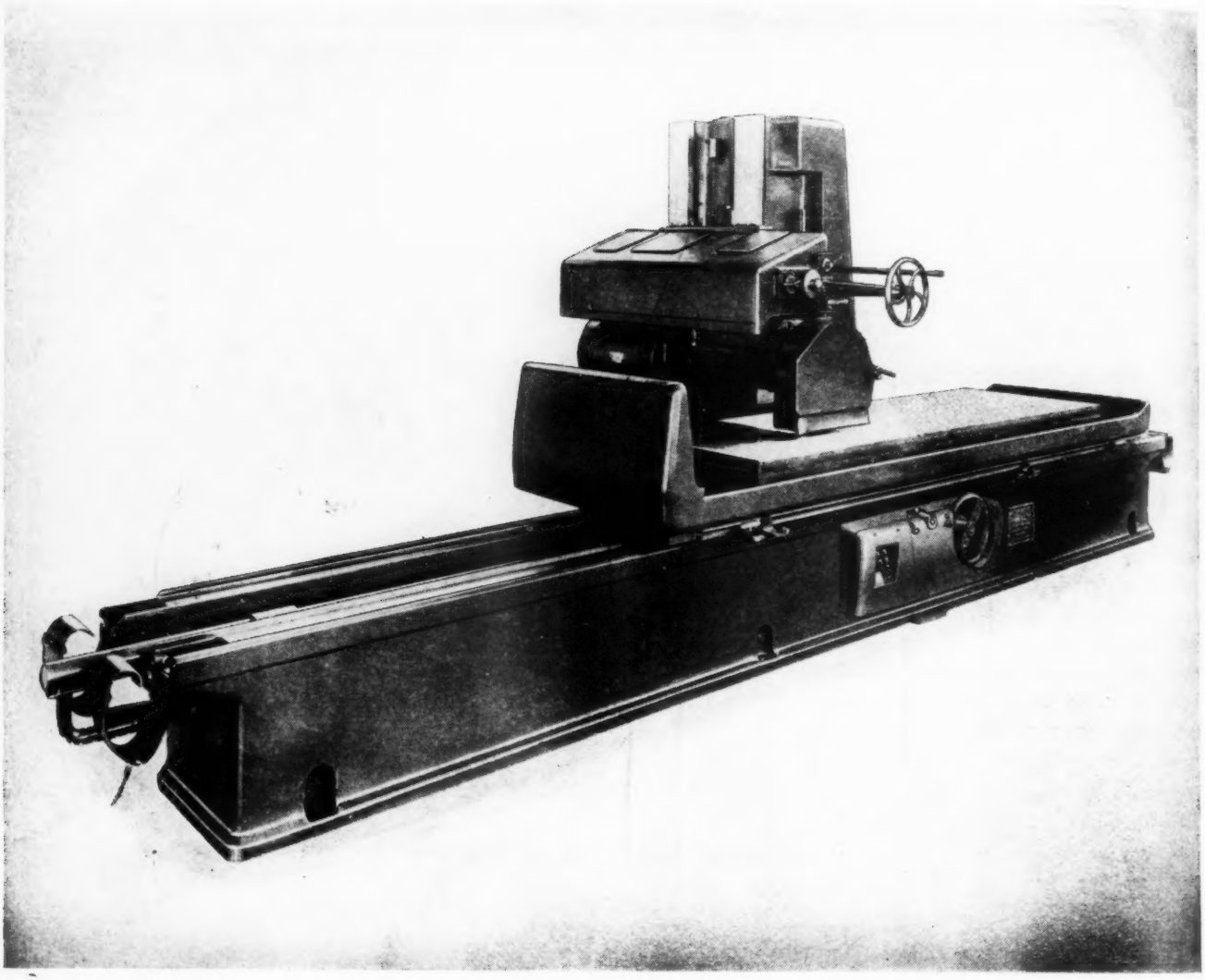
The number of punch press operations on this hermetically sealed compressor housing were reduced by designing shallower depressions in the housing shell and substituting mounting brackets that are projection welded to the housing. A large base was replaced by two stamped legs thus saving material and reducing the number of press operations. The gage of the brackets was changed to correspond with the housing material, which permitted the salvaging of the scrap corners from housing stamping operations. Housings are made by the Acklin Stamping Co., Toledo, Ohio, for the Tecumseh Products Co., Tecumseh, Mich.



UPPER HOUSING has two mounting brackets that are projection welded on the outside of the housing. The stampings for this assembly and all other stampings except the terminal plate are made from 0.1196 in. thick hot rolled, pickled and oiled sheet steel.



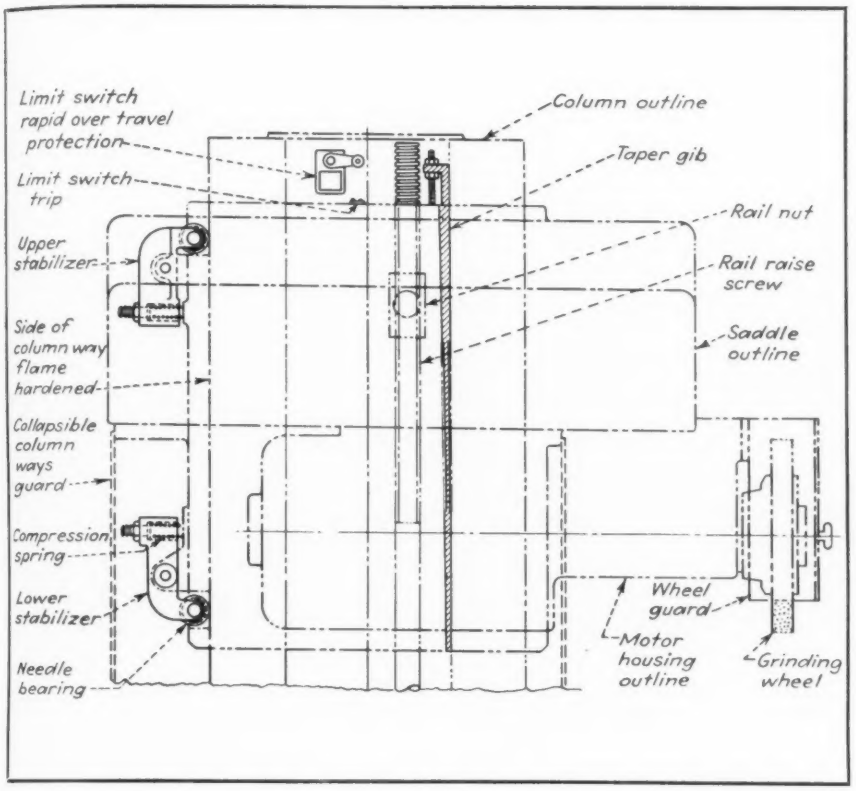
LOWER HOUSING has two stamped legs projection welded on the bottom. In assembling, spring studs are first swedged to the internal mounting brackets. Three terminal bushings are welded to the housing. The terminal plate is then assembled to the housing by projection welding. The three internal mounting bracket assemblies are welded to the housing in one operation. Terminal plate is 0.2187 in. thick hot rolled, pickled and oiled steel stock. Only the terminal bushings and spring studs are not stampings.



Needle Bearing Stabilizers Maintain Alignment

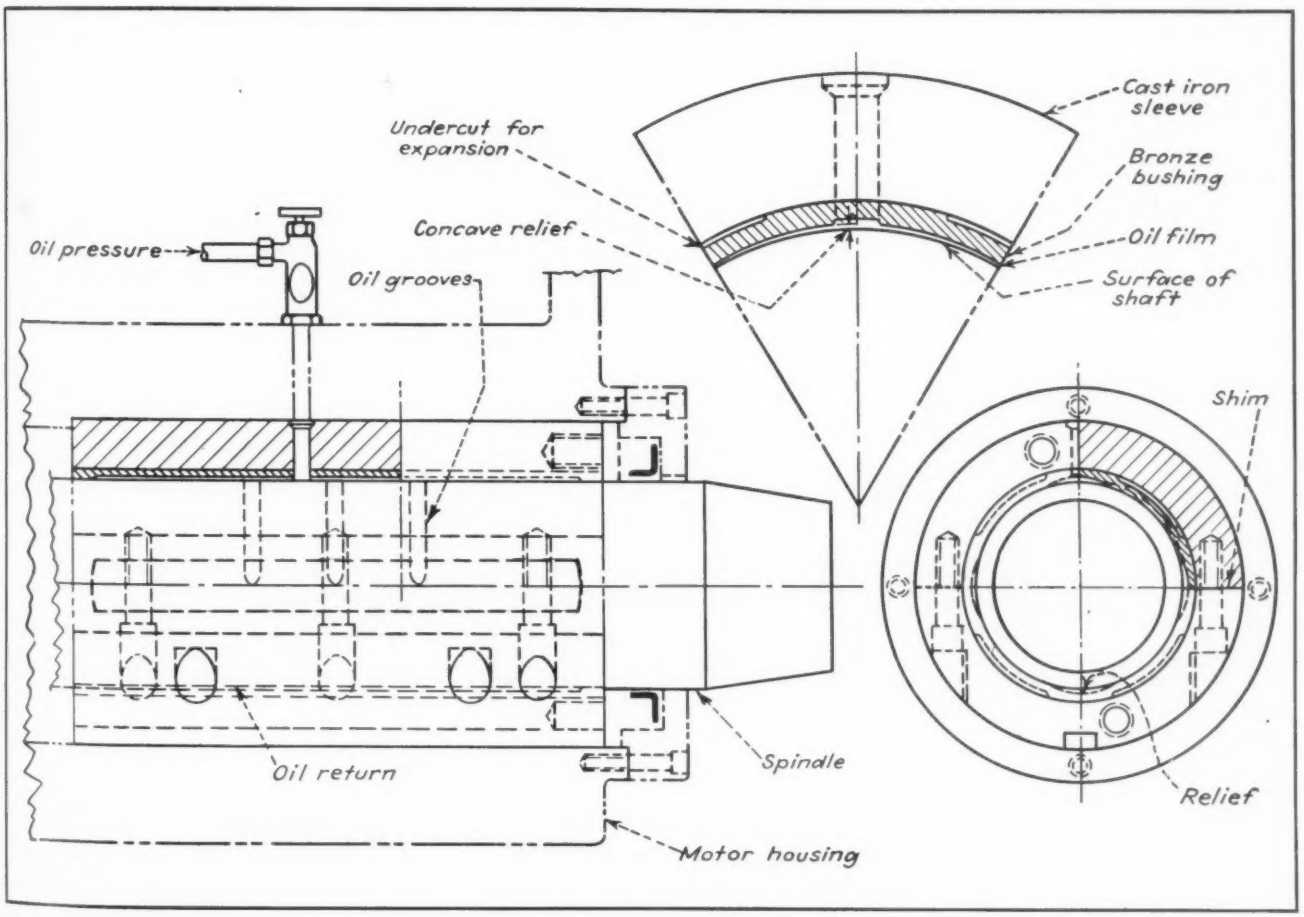
Open Side Horizontal spindle Hydraulic Surface Grinders built by the Hill Acme Co., Cleveland, Ohio, have needle bearing stabilizers that maintain grinding wheel spindle alignment. A double hydraulic system provides independent operation for the table and cross feed, thus permitting the wheel to be dressed by power. Hydraulic cross feed can be set at a constant feed or adjusted for $\frac{1}{8}$ in. to 2 in. jump feed at each reversal of the table. Spindle head can be manually operated or locked in place for form grinding operations. Grinders having these features are built in three table widths: 18 in., 24 in. and 30 inches. Bed length is approximately twice table length.

Open side grinder has cast alloy bed of box type construction with machined flat and vee ways. Table is also an alloy casting that is ribbed and normalized to prevent warping. Table ways are ground. Cast alloy column has ground bearing surfaces for supporting wheel head. Five electric motors are used in this machine. They include: a fan cooled spindle motor, hydraulic pump motor, rapid traverse hoist motor, ways lubricating pump motor and coolant pump motor. Hydraulic table drive system is operated by a Vickers vane type rotary pump, which supplies oil to two opposing pistons. Variable table speeds from 10 to 100 rpm are possible. No gears are used in either the table drive or cross feed drives. Pumps and valves are in a steel tank. All operator controls are mounted in the panel at the front of the machine. One-shot lubrication system provides lubrication for 19 points in the grinder. Welded steel coolant tank is at the rear of the machine.



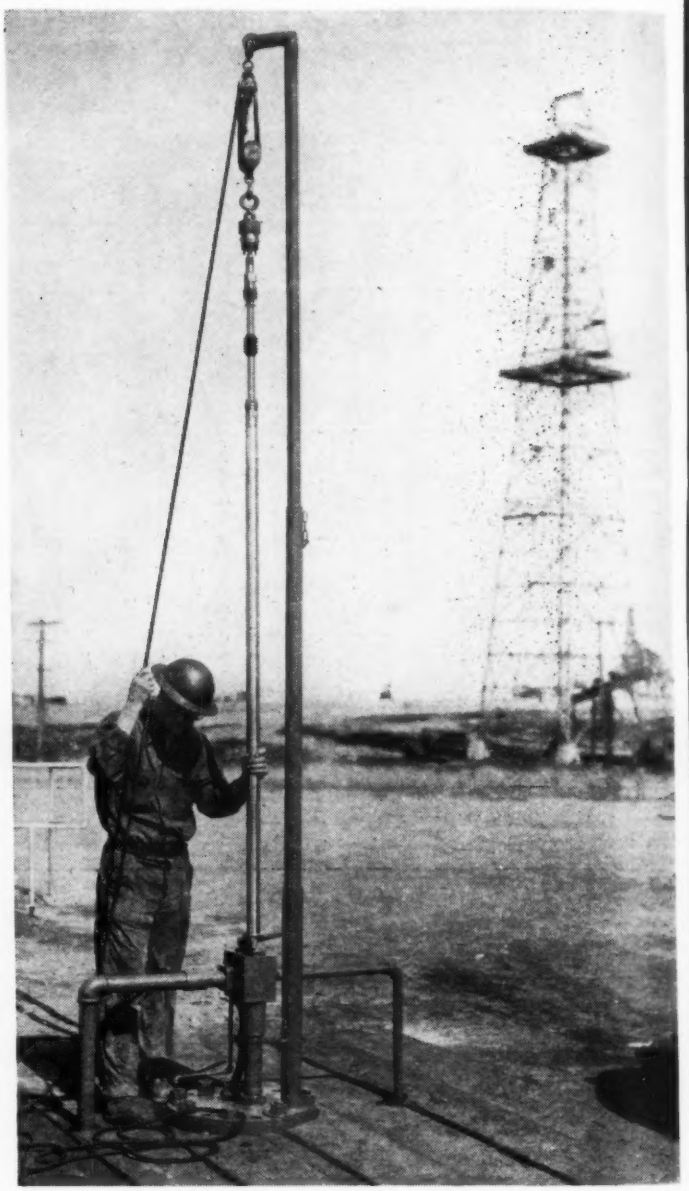
TWO SPRING TENSION needle bearing stabilizers are mounted on the saddle at the back of the grinder. They travel on the flame hardened ground column bearing surface. These stabilizers maintain spindle alignment while the grinding wheel moves across the work. A long adjustable tapered steel gib is included in the saddle to supplement the stabilizers in maintaining alignment.

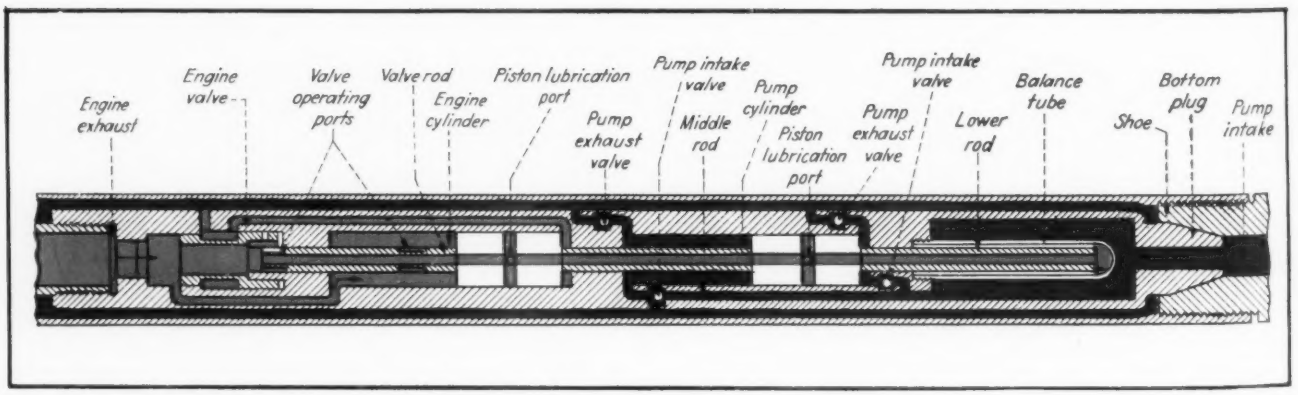
SPINDLE BEARINGS are built into the 25 hp motor housing. Rear bearing is an extra heavy precision preloaded double row ball bearing designed to carry end thrust and radial load. Front spindle bearing shown is adjustable and is provided with pressure lubrication. It consists of a cast iron sleeve and bronze bushing assembly. Bushing is undercut on the outside diameter to allow for expansion. Inside diameter of bushing has concave relief and oil grooves. Adjustment is made by shimming the two halves of the bearing insert.



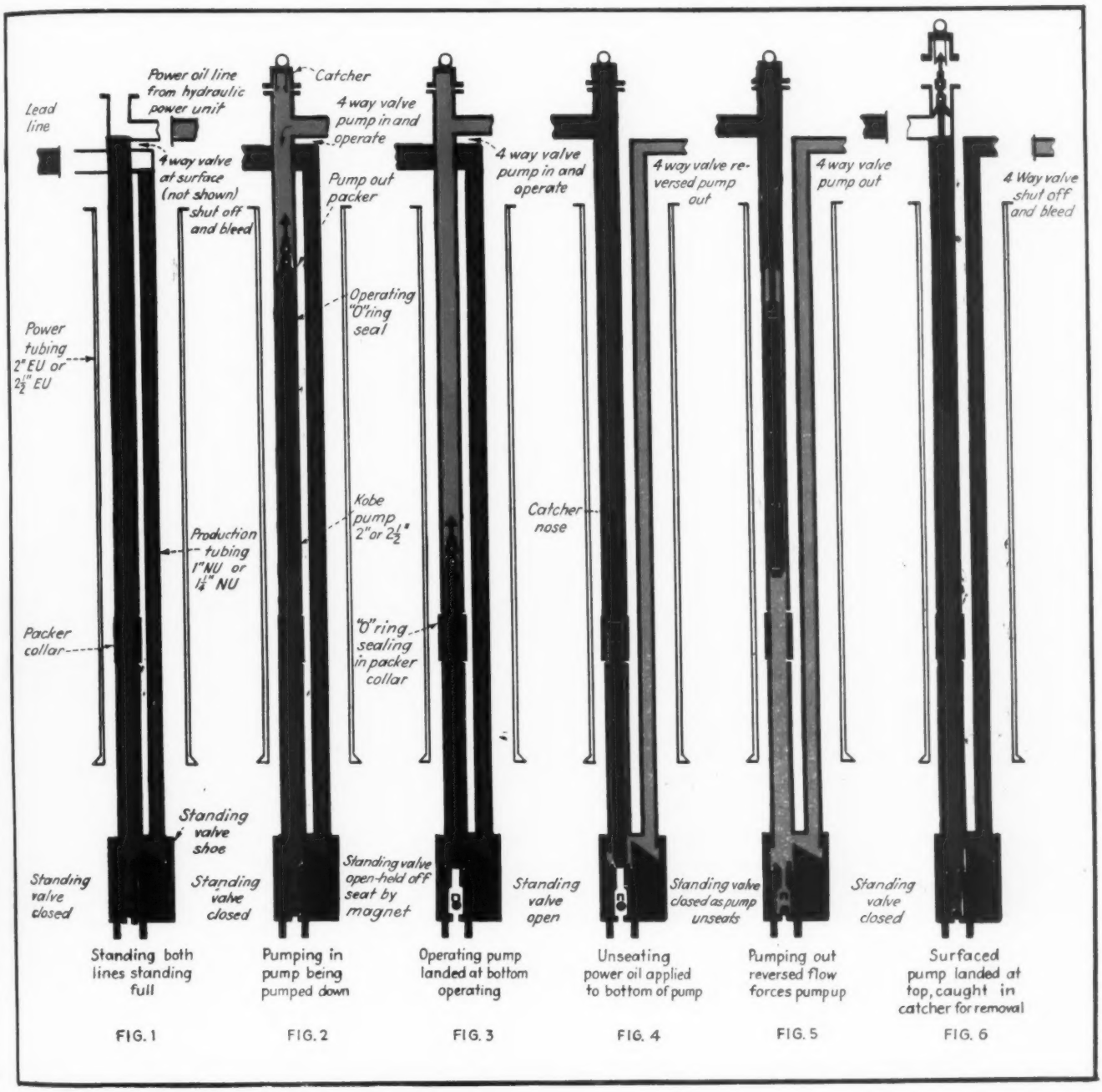
Hydraulic System Seats and Lifts Oil Well Pump

The Kobe Free Type Pumping system uses hydraulic pressure to seat, operate and lift a subsurface hydraulic oil well pump. Developed by Kobe Inc., Huntington, Calif., this system reduces the number of men and time required to lift deep well hydraulic pumps for repair operations. Rod or fixed type hydraulic pumps require a crew of four men working 8 hr to pull and re-run the pumps to a depth of 5000 feet. The Kobe system permits one man to retrieve and re-run the pump to a depth of 5000 ft in less than two hours. Three types of installations are used with this system: parallel-string, concentric-string and casing type. The Parallel-string installation is described. Pump production unit is trapped by a catcher device when it reaches the top of the power tubing. The catcher and pump assembly are lifted by a block and tackle suspended from a rod extension mounted on the flange on top of the casing. Production units range in sizes from 1⅞ in. dia by 78½ in. long to 3 13/16 dia by 204 in. long.





SUBSURFACE PRODUCTION UNIT consists of a hydraulic engine and a displacement pump. The engine at the left of the unit is a double acting reciprocating hydraulic engine with motion controlled by a hydraulic valve. Engine is driven and lubricated by the power oil which is transmitted from the surface through small tubing and exhausted into the production column. Pump at the right of the unit is a double acting reciprocating piston pump. Pump piston is driven by a middle rod that is connected to the piston of the engine. Pump intake is located at the right, which is the bottom of the unit. Piston and rod system is drilled for hydraulic balance and lubrication.


Power oil line from hydraulic power unit
Lead line
4 way valve at surface (not shown) shut off and bleed
Power tubing 2" EU or 2½" EU
Production tubing 1" NU or 1¼" NU
Packer collar
Standing valve closed
Standing valve shoe
Standing valve closed
Standing both lines standing full
FIG. 1
Catcher
4 way valve pump in and operate
Pump out packer
Operating "O" ring seal
Kobe pump 2" or 2½"
"O" ring sealing in packer collar
Standing valve open-held off seat by magnet
Pumping in pump being pumped down
FIG. 2
4 way valve pump in and operate
Catcher nose
Standing valve open
Operating pump landed at bottom operating
FIG. 3
4 way valve reversed pump out
Standing valve closed as pump unseats
Unseating power oil applied to bottom of pump
FIG. 4
4 way valve pump out
Standing valve closed
Pumping out reversed flow forces pump up
FIG. 5
4 Way valve shut off and bleed
Surfaced pump landed at top, caught in catcher for removal
FIG. 6

PARALLEL SYSTEM shows the tubing arrangement in a well. With standing valve closed both power and production tubing stand full of oil. A four way valve, not shown, at the surface has three operating positions: "shut-off and bleed," "pump in" and "surfacing."

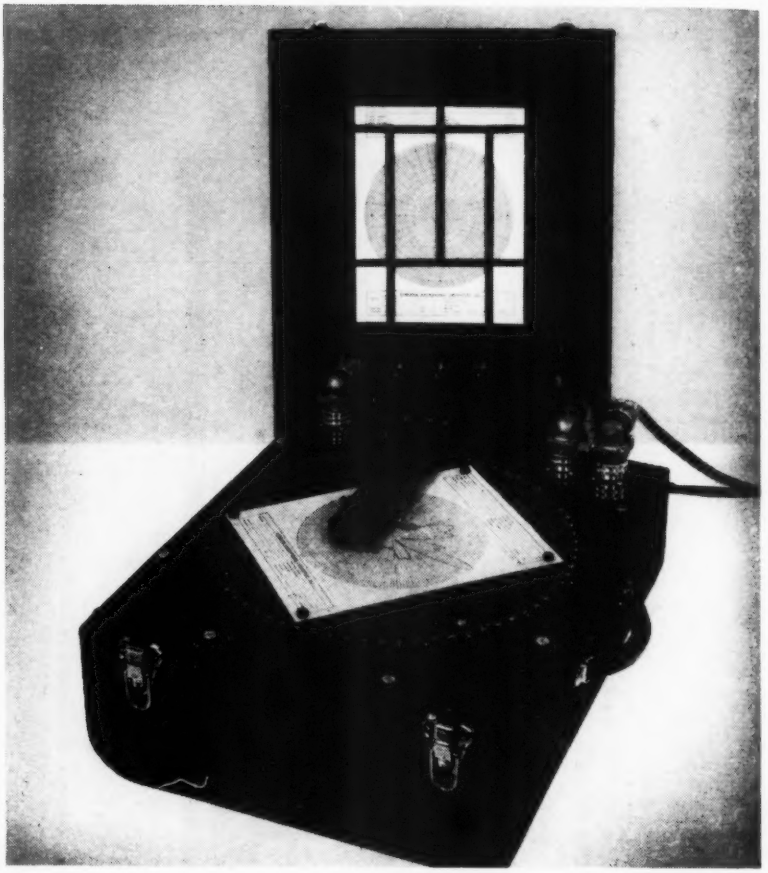
The shutoff and bleed position is shown in Fig. 1. Standing valve assembly is retrievable and can be pulled by a fishing tool on a wire line. A knockout bleeder pin, which is broken by the tool, is built into the valve. Standing valve is held off seat magnetically during pumping operations.

In Fig. 2 the pump is shown inserted with the catcher head assembly in place and the tubing closed. Power oil is circulated down the large tubing, pushing the pump down. The pump has reached the bottom-seating in the shoe in Fig. 3. The 0-ring on the pump is in the packing collar. The power oil forces the 0-ring to seal and the pump operates. Pumped fluid and exhausted power oil return to the surface through the small tubing.

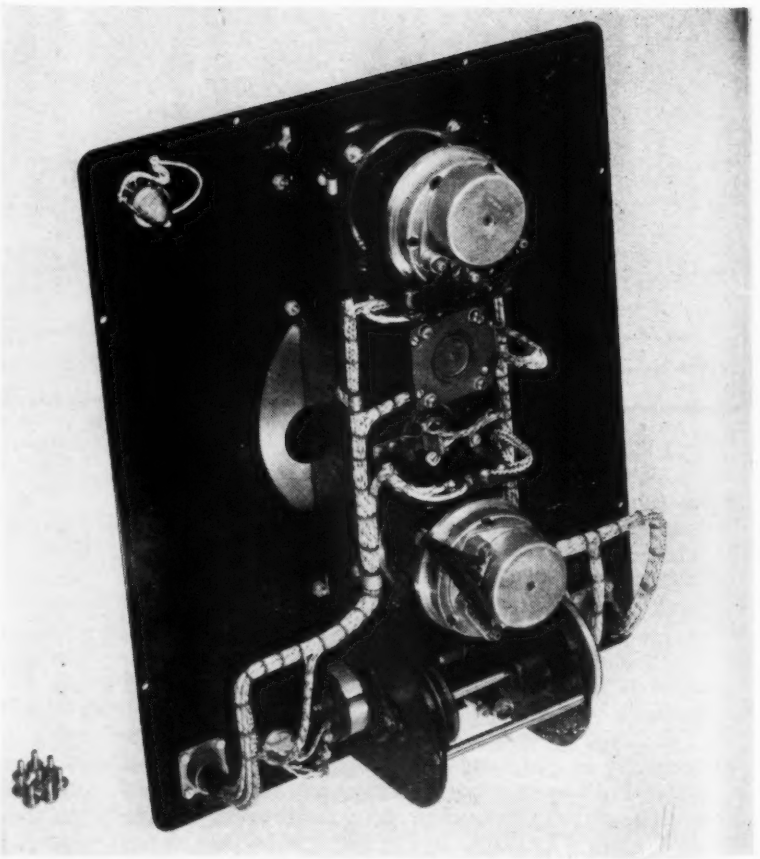
The surfacing operation has begun in Fig. 4. Four way valve at surface has been turned to direct the power oil down the small tubing. As the pump unseats, a quick rush of oil through the standing valve overcomes the magnet force and the ball check closes.

The flow is shown in Fig. 5 forcing the pump up the tubing. When the pump is forced from the seat, the full area of the pump packer becomes effective lift area and a smaller amount of pressure is required to surface the unit. Oil pressure in the power line builds up to 850 psi when it kicks pump unit off seat and drops below 500 psi as the pump starts up the tubing. The pump has reached the surface in Fig. 6 and is latched in the catcher. Four way valve is in the shutoff and bleed position and the catcher has been loosened to lift pump from tubing.

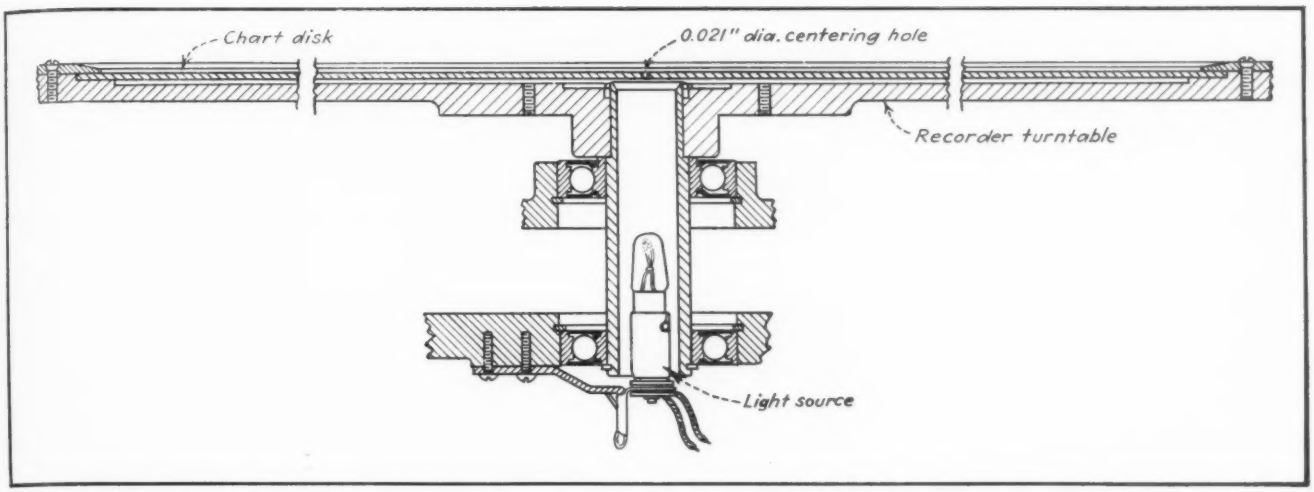
Polar Recorder Has Optical Centering Device

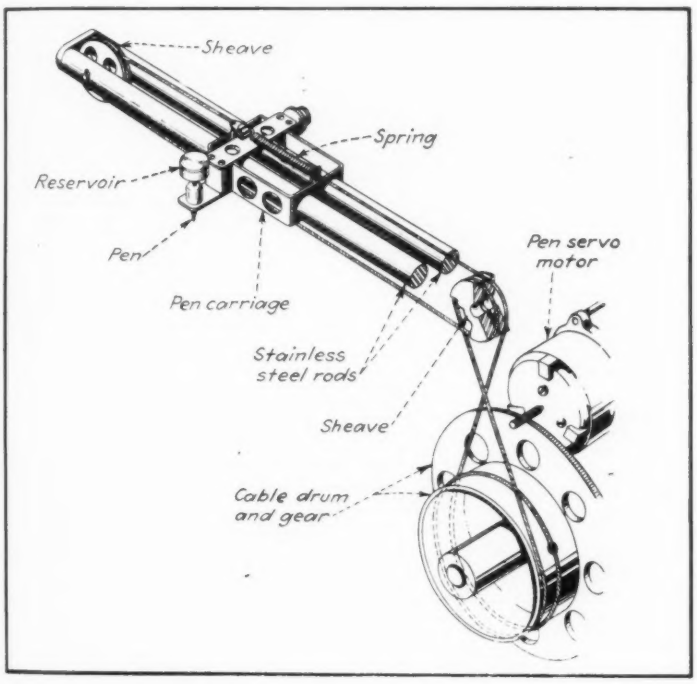


A light source placed beneath a 0.021 in. dia. centering hole in a recorder turntable permits the centering of charts on the A.I.L. type 116 Polar Recorder developed by Airborne Instruments Laboratory Inc., Mineola, N. Y. Designed originally to plot aircraft antenna radiation patterns, the recorder will chart voltage on either a linear or a logarithmic scale as radial distance against angular position. An ink trace approximately 0.025 in. wide is obtained by a combined pen and reservoir carried on a low inertia carriage.



PORTABLE RECORDER is inclosed in a gasketed steel carrying case. Standard $8\frac{1}{2}$ in. by 11 in. rectangular polar plotting paper or a $13\frac{1}{8}$ in. dia circular chart can be used on the turntable. Chart is held on the steel chart table with small Alnico magnets. This method of mounting the chart facilities rapid removal of ink charts. Controls are provided for pen carriage zero adjustment and for manual control of speed and direction of turntable rotation.

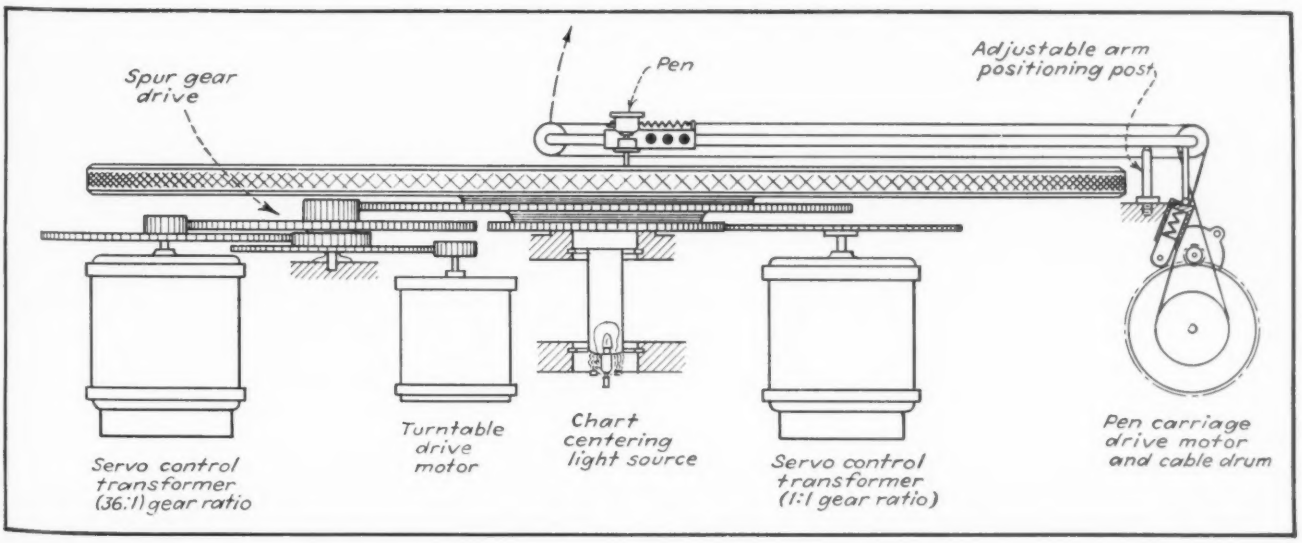




OPTICAL CENTERING DEVICE is made by mounting an incandescent lamp in the hollow turntable spindle beneath the centering hole. Turntable shaft is supported by two roller bearings.

PEN CARRIAGE is driven by the pen motor through a gear reduction and cable drive. Spring keeps cable tight on pulleys and drum. By using a stainless steel pen carriage sliding on stainless steel rods, the tendency of dust to pack under the rods of a roller-supported carriage is avoided by the sliding action which continuously cleans the rods. Light construction of the pen carriage and carriage drive reduces inertia forces that often cause overtravel of the pen.

DRIVING MECHANISM is mounted beneath the turntable. Frame, turntable support and pen carriage arm are cast aluminum. These parts are dipped, primed and painted to prevent corrosion. All gears and most of the small parts are free-machining stainless steel, which does not require plating for either resistance to corrosion or improved sliding characteristics.


Spur gear drive
Pen
Adjustable arm positioning post
Servo control transformer (36:1) gear ratio
Turntable drive motor
Chart centering light source
Servo control transformer (1:1 gear ratio)
Pen carriage drive motor and cable drum

Notch Toughness of Steel Plates

D. F. WINDENBURG
Chief Physicist, David Taylor Model Basin

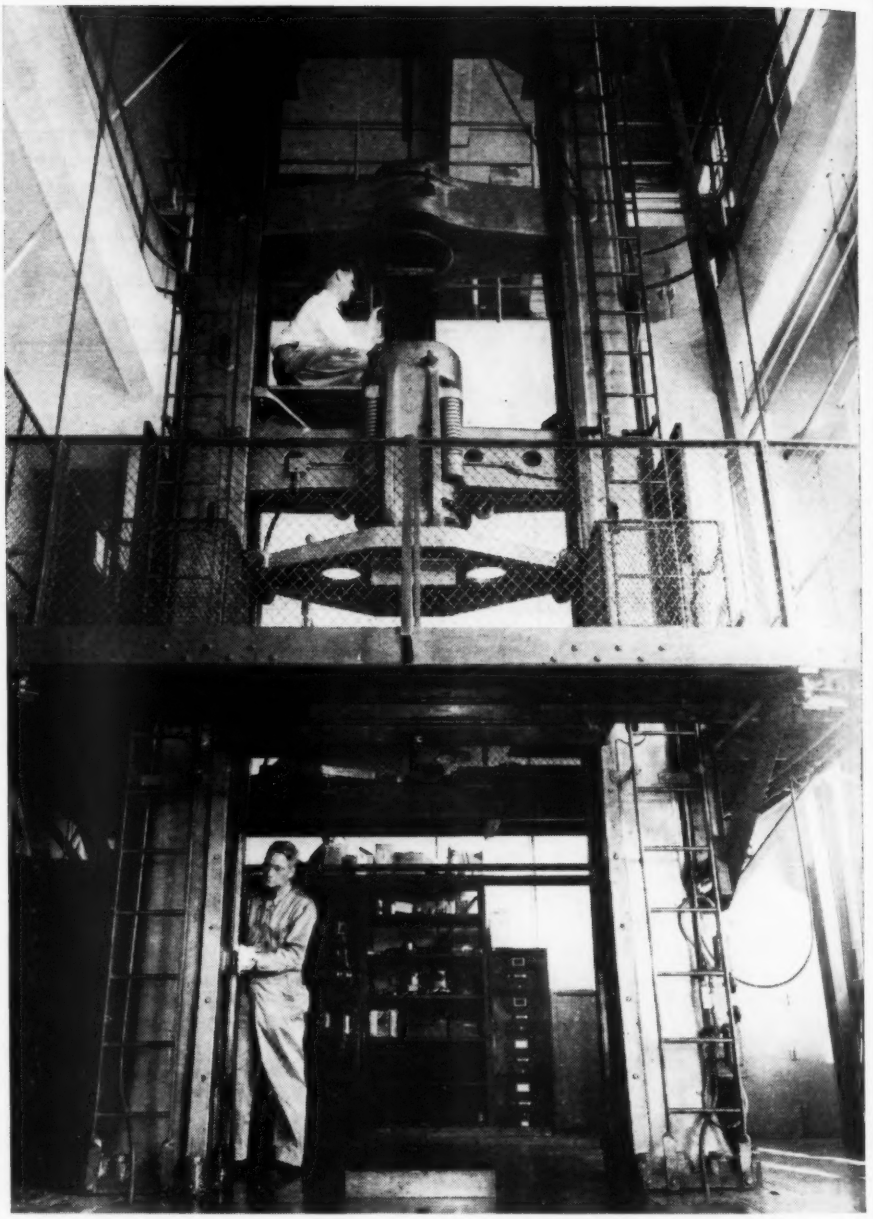


Fig. 1—The ¾ in. steel plate in this 600,000-lb universal testing machine, at the David W. Taylor Model Basin, is being tested in connection with a study undertaken to investigate and determine the causes of structural failures of welded merchant ships.

THE PROBLEM of how to measure notch toughness of steel plates has not yet been solved, but much progress toward a better understanding of the basic behavior of notched specimens has been made. On April 20, 1943 a board was convened by the Secretary of the Navy to investigate the causes of fracture that were then occurring in welded merchant vessels. A month later the board appointed a sub-board to study the entire problem in detail.

The economical method of approach to the problem was to investigate in sequence the three phases: Design, fabrication, and materials. But since this was the most crucial period of the war, time was all-important; consequently all three phases were investigated simultaneously. The immediate issue was how to save the vessels then in service from fracture and how to build the rest of the merchant fleet so that the vessels would not fail in service.

For background information, the sub-board made a careful study of all the ships that had fractured in service. This study brought out many important facts, some of which have been enumerated in the previous article "Significance of Impact-Test Data in Design of Engineering Structures," PRODUCT ENGINEERING, September, 1946, p 81. This study called attention to poor design in the form of discontinuities in certain strategic places. Discontinuities are always potential sources of trouble, but if properly faired without abrupt transitions excessive stress concentrations can usually be avoided.

Another result of this study was to show that many of the cracks started in or near welds, especially at cracks adjacent to the welds. This pointed the finger of suspicion towards the welding, especially since it was well known that the welding process produced severe residual and locked-in stresses. Considerable difference of opinion existed as to how important these stresses were in causing cracking, many people believing that they were the major source of the trouble. This phase of the problem was attacked energetically by several different laboratories under the direction of the sub-board through the War Metallurgy Committee of the NDRC. They found high residual stresses and high locked-up stresses, as was suspected, but they were unable to find real evidence that these stresses were an important factor in the fracture of welded merchant vessels

One important fact brought out by the study of fractures was the peculiar

The opinions expressed in this article are those of the author and are not to be construed as official opinions of the United States Navy Department.

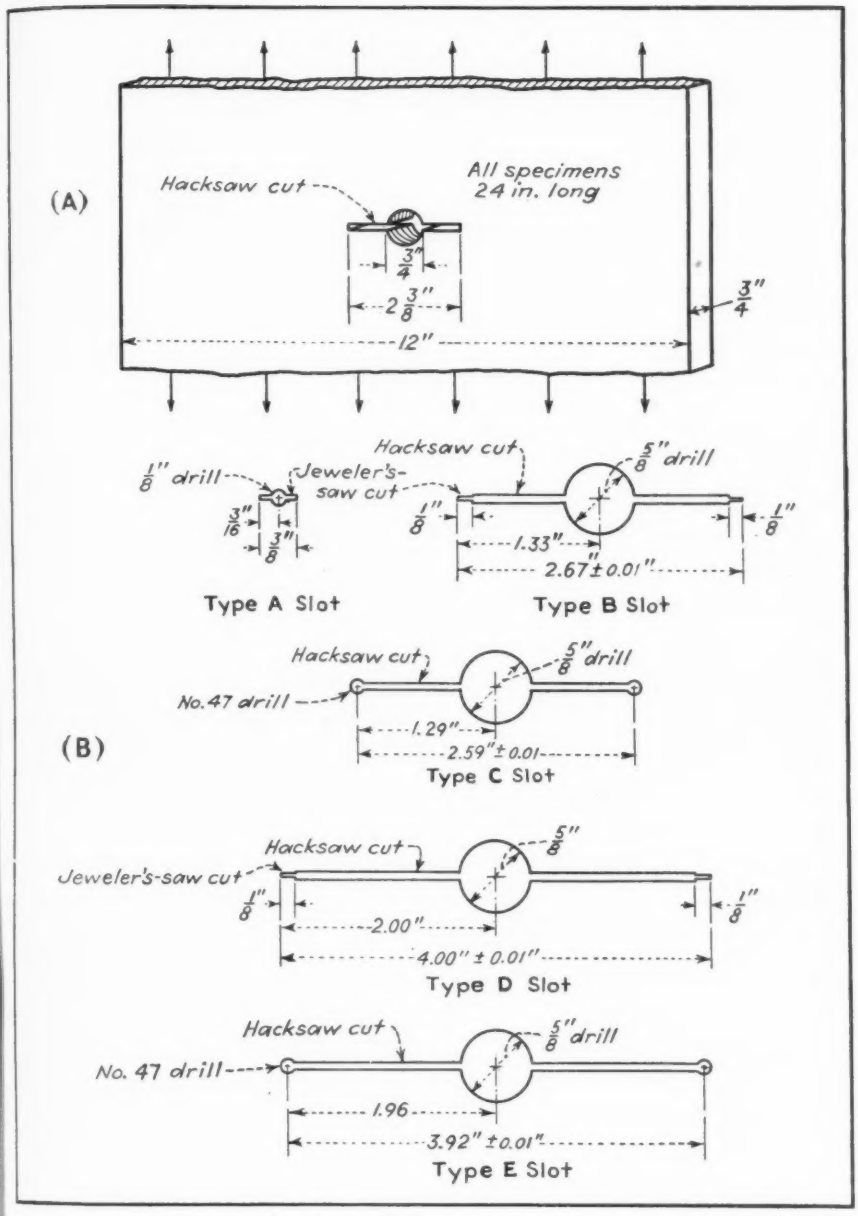


Fig. 2—(A) Form of a typical tensile-test specimen. (B) Details of some of the internal slots cut in the tensile-test specimens. For each type of notch, specimens were tested over a temperature range such that fractures were both of the shear and of the cleavage type.

fracture of the steel. The cracks were all of the cleavage type, that is, the surface of separation was perpendicular to the plane of the plate; whereas, when coupons were cut from the same material and pulled in a static testing machine the ruptures were of the shear type with the surface of separation at approximately 45 deg to the plane of the plate. Moreover, when fractured in a ship, the plating absorbed only a small amount of energy as was manifested by the low ductility and the negligible amount of thinning at the fracture, whereas, when coupons were pulled statically they absorbed a large amount of energy and met the standard ABS Specifications for ductility. These observations indicated that the material did not behave the same in the ships as when tested under standard acceptance tests. Something in the ships was apparently inhibiting the ability of the plating to flow plastically. Consequently, serious study was given to the steel itself.

After the many years of building steel ships, it seems rather anomalous that structural engineers did not have a good basic understanding of the properties of the steel from which the ships were built. Shipbuilding steel had been taken for granted as long as it met standard ABS specifications. Here engineers were confronted with a situation where the common garden variety of shipbuilding steel did not live up to expectations based on acceptance tests. In a word, when built into a ship, the steel seemed to lose its ability to deform plastically and thereby to absorb energy.

Along with other laboratories, the David Taylor Model Basin was assigned the job of investigating the behavior of shipbuilding steel. It was known from simple theory that triaxial tensile stresses resulted in low shearing stresses and thus inhibited plastic flow. It was also known from experiment that steel became less ductile as the temperature was decreased, becoming brittle at low temperatures.

It was difficult, however, to envision conditions on a ship that would reduce the shearing stress and the ductility so much that brittle fractures would occur at nominal working stresses.

Tensile Test Specimens

To develop some type of tensile specimen by which the transition from ductile to brittle fracture could be studied in plate specimens of appreciable size, tests were made on specimens of the full thickness of the plating and of widths ranging from 3 to 72 in. Most of the specimens tested at the Taylor Model Basin were of rimmed steel, $\frac{3}{4}$ in. thick, 12 in. wide, and 24 in. long. Internal slots, terminating in notches of different types, were cut in the specimens before testing. A typical tensile test specimen and details of some of the internal slots are shown in Fig. 2. The length of the slots ranged from $\frac{3}{8}$ to 9 in. Also, to obtain different sharpnesses of notch at the ends of the slots, radii of about 0.01 to $\frac{3}{8}$ in. were used. Slots of Types A, B, and D terminated in a jeweler's-saw cut. Slots of Types C and E terminated in a drilled hole corresponding in radius to the notch of a keyhole Charpy test specimen. Drilled holes $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ in. dia were also used.

The specimens were pulled in a static testing machine at constant temperatures. Care was taken to maintain the temperature constant throughout the progress of the tests. In regions where the most severe plastic flow was expected, the temperature was checked by several thermocouples peened in the specimens. The heat caused by the plastic flow was dissipated after each increment of load before the next increment of load was applied. Thus the specimens were tested under essentially isothermal conditions. For each type of notch, a series of specimens was tested over a temperature range such that the fractures were both of the shear and of the cleavage type.

Most of the specimens were ruled with grids of equally-spaced fine lines, so that the plastic deformations could

be observed. Besides visual observations of deformations and the type of failure, the overall elongation was measured for each increment of load. Thus, from the data it was possible to determine the total amount of energy absorbed by each specimen, as well as its ultimate load, the load at which yielding began, and the type of fracture. It was realized that the total energy absorbed gave but a poor indication of the energy absorbed per unit volume at points of high plastic flow, but these tests were intended to be exploratory only and were to be used in pointing the way to a type of specimen that would give the basic information required.

Results of Tests

Some of the specimens tested are shown in Figs. 3, 4, and 5. Fig. 3 shows a specimen under test at a temperature of 100 F. Note the intense local strain at the ends of the notch. Although this notch terminated in a jeweler's-saw cut, the severe plastic flow has so changed the shape of the notch that it appears to terminate in drilled holes about $\frac{1}{4}$ in. in diameter.

The specimen shown in Fig. 4 has begun to rupture. This type of rupture is referred to as shear rupture. The surface of rupture is on a shear plane about 45 deg to the surface of the plate. The specimen has elongated considerably under load and consequently has absorbed a large amount of energy before rupture.

In Fig. 5 is shown a specimen after cleavage fracture at a temperature of 75 F. Both faces of the fracture are shown. It will be observed that the fractured surfaces are perpendicular to the surface of the plate. This specimen elongated only slightly under load and consequently absorbed only a small amount of energy before fracture.

The results of the tests conducted at the David Taylor Model Basin can best be visualized from an inspection of the plotted data. If the plates behaved as Charpy impact specimens, a plot of energy absorption on a basis of temperature would be instructive. Typical Charpy impact curves for semi-killed and fully-killed medium steel are shown in Fig. 6. Note the steep slope of the curves in the transition region between high-energy and low-energy values. In this transition region, there is usually considerable scatter of the data. The temperature at which the energy values begin to decrease rapidly is generally referred to as the transition temperature.

A similar plot of the data obtained from the tests of plates with internal notches is shown in Fig. 7. The energy required to fracture the specimens is shown plotted on a basis of the temperature at which the specimens were tested. For all of the specimens represented here, the length of the slot was about one-fourth the width of the plate. The values of energy shown are average energy per square inch of net cross-section. The data plotted here indicate some interesting trends. For example, it is seen at a glance that the energy values are much higher for the plates with slots terminating in large holes than for the plates with slots terminating in small holes or in sharp jeweler's-saw cuts. Also, although some of the plates with holes $\frac{1}{2}$ and $\frac{3}{4}$ in. dia showed definite transitions from shear to cleavage fractures, these transitions are not reflected in increased energy absorption.

Comparison With Charpy Tests

Only the two curves for the sharper notches bear any resemblance to the typical curves obtained from Charpy impact tests. In these curves, the circled points represent shear rupture; the specimens marked C-S started as cleavage fractures and ended as shear fractures; the other points represent cleavage fractures. Although the cleavage fractures started at a temperature of about 100 F, it is entirely possible that all the data shown for temperatures above 100 F are still within the scatter zone typical of Charpy tests, and that the upper transition temperature was not yet reached at 150 F, the upper temperature used for the lower two curves.

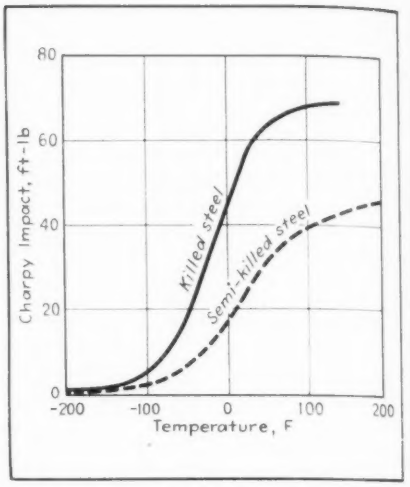


Fig. 6—Typical Charpy-Impact curves over a wide temperature range for semi-killed and fully-killed medium steel.

Energy Required to Fracture

These same data, between temperatures of —40 and 75 F are shown plotted in a different form in Fig. 8. Here the energy required for fracture is shown plotted on a basis of the diameter of the holes at the ends of the slots. It will be observed that these data can be represented fairly well by a straight line. The trend is certainly linear; thus it can be inferred that the energy required to rupture plates of this type is approximately equal to a constant times the diameter of the holes at the ends of the slots.

For the plates with slots terminating in a jeweler's-saw cut, and for those with slots terminating in holes 0.08 in. dia, there were sufficient data

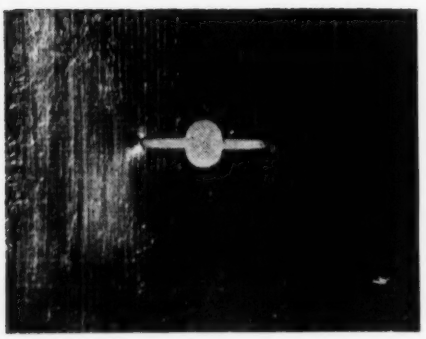


Fig. 3—Specimen under test at a temperature of 100 F. Notch terminated in a jeweler's-saw cut, but plastic flow has changed the shape of notch.

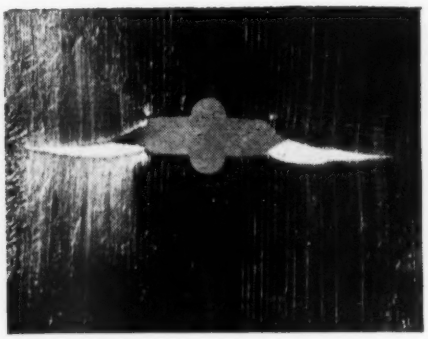


Fig 4—Beginning of shear rupture in a notched tensile specimen. The specimen has elongated considerably before rupture and has absorbed a large amount of energy.

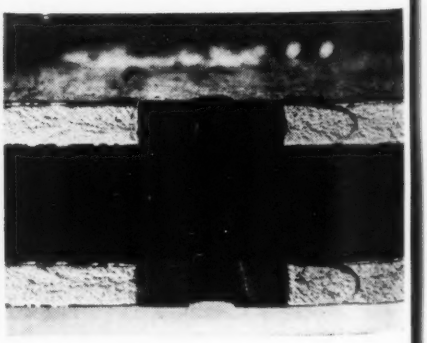


Fig. 5—Cleavage fracture of a notched specimen tested at a temperature of 75 F. Fractured surfaces are perpendicular to the surface of the plate.

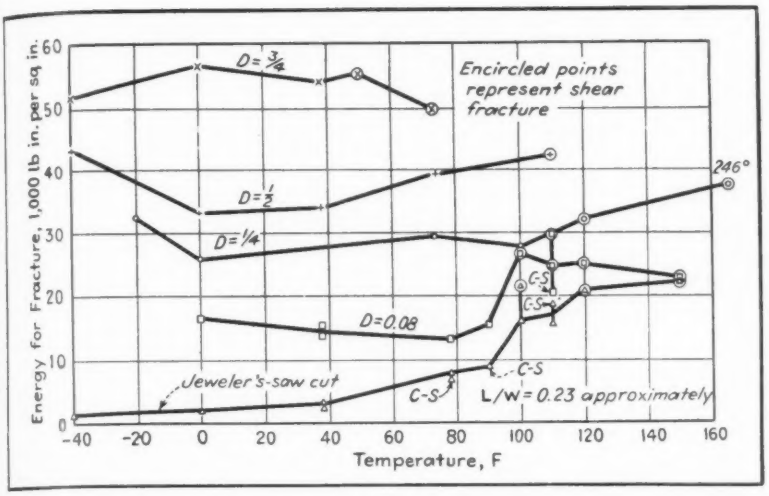


Fig. 7—Energy for fracture plotted on a basis of temperature for notched tensile specimens made from rimmed-steel ship plate. Energy values are higher when the slots terminate in large holes than when they terminate in small holes.

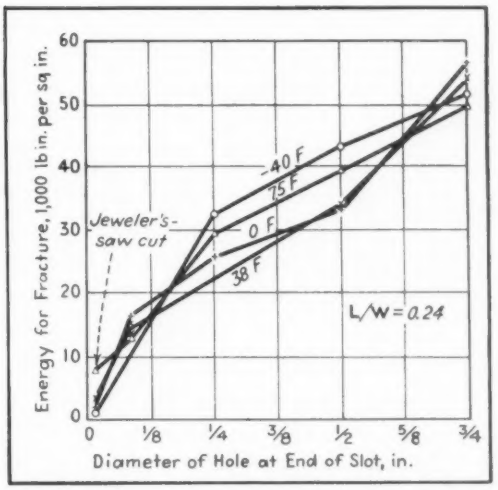


Fig. 8—Energy for fracture plotted on a basis of diameter of terminal holes in slot. Energy required to rupture the plates is approximately linear.

to indicate the trend of energy absorption as a function of the length of the slot. These data are shown plotted in Fig. 9. Since the energy values are calculated on the net area, the plates with different lengths of slot can be compared on an energy basis. Here, energy required for fracture is shown plotted on a basis of the ratio of the length L of the slot to the width W of the plate These data are far from linear. At first sight, no functional relationship is apparent. From a statistical analysis, however, Captain W. P. Roop of the Taylor Model Basin came to the conclusion that the energy varied inversely with L/W. Thus the energy required for rupture is roughly equal to W/L times a constant.

As previously pointed out, these tests were merely intended to be exploratory. Any incidental conclusions that can be drawn from the data are fortuitous. As a result of the tests thus far conducted, it is believed that tensile specimens with internal notches, similar to those described in the foregoing, can furnish useful information on the performance of the material in a ship. The specimens with the shorter notches terminating in a jeweler's-saw cut or possibly in a small drilled hole seem to be preferable.

The specimens have the advantage that they take in the full thickness of the plate. They clearly show a transition temperature between ductile shear and brittle cleavage fracture. They are symmetrical in shape and have an appreciable amount of triaxial stress at the root of the notch. Moreover, they are of such a shape that the stress condition at the root of the slot, preceding fracture, can be approximated. Photoelastic investigations in three dimensions, made by the Carnegie Institute of Technology, showed the distribution of triaxial stresses at the root of the notch, in the elastic range, for plates of thicknesses from $\frac{1}{8}$ to 1 in. They did not show, however, how the stress condition changed when plastic flow began. The photoelastic investigation is now being supplemented by a theoretical investigation, by Armour Research Foundation, of the elastic stresses at the root of the notch. It is hoped that this theoretical investigation can later be extended into the plastic range.

More Research Needed

The problem of notch toughness of steel plates is far from solved. Much progress has been made, but there is still much more work to be done before suitable tests can be developed that will assure satisfactory performance of steel in ships. The problem is an exceedingly complicated one because of the large number of variables present. Even the thickness of the plating is believed to be an important factor.

The tensile specimens discussed in this article have given useful information and may point the way to a specimen suitable for acceptance tests. Mr. N. A. Kahn of the New York Naval Shipyard believes that the energy required to tear the plate in two after parting has begun is the really significant quantity, and has developed a specimen to give these data. Dr. A. Nadai of the Westinghouse Research Laboratories is making a thorough study of the size effect in steel. Tests on ship plates up to 72 in. in width have been conducted at the University of Illinois and at the University of California.

Tests on full-scale hatch corners have been conducted at the University of California. These tests are continuing, both to study the behavior of the corners and to study the notch toughness of steel built into large assemblies. Tests of large box girders have been conducted at the National Bureau of Standards. Theoretical studies are underway at the Armour Research Foundation and at the University of Illinois. A study at Pennsylvania State College of all the tests that have been conducted is being made in the hope of correlating laboratory data with the full scale performance of ships. Because of the wide interest that has been developed in this work, it is believed that progress will continue at an accelerated rate and add much to existing data on the notch toughness of steel plates.

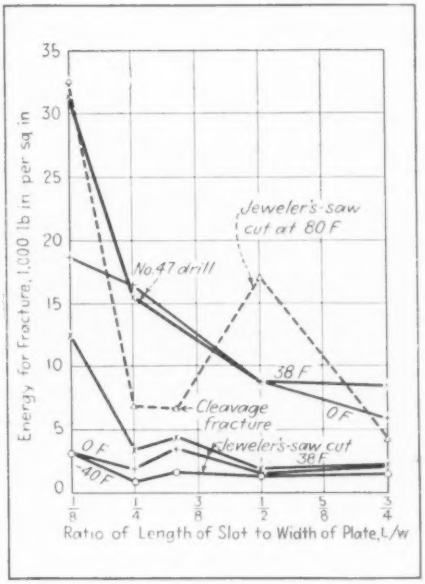

Energy for Fracture, 1,000 lb in. per sq in.
Ratio of Length of Slot to Width of Plate, L/w
Jeweler's-saw cut at 80 F
No. 47 drill
38 F
0 F
Cleavage fracture
Jeweler's-saw cut
-40 F

Fig. 9—Energy for fracture plotted on a basis of the ratio of length of slot to width of plate.

Progress in Review

In this running summary of technical developments, space restrictions do not allow giving complete details. Further information relating to any item can be obtained by writing to the Editor of Product Engineering.

PLASTICS AND RUBBER

PLASTICS SALES in 1947 reflected the transitory condition of the plastics industry. The year started badly for plastics manufacturers and by the summer reached a frighteningly low point. By the end of the year, however, business picked up, and now sales are on their way back to the all time high of 1946.

What happened? The "fly-by-nights" and inexperienced operators were squeezed out of business by normal, postwar competition. These misfits, who specialized in misapplying materials and bad workmanship, were well on the way toward hurting consumer acceptance of plastics. Now, responsible members of the plastics industry are having their way: Plastics are not being applied as substitutes, but only where they belong. 1948 will see a continuation of this trend, with emphasis on sound engineering practice and informative merchandising.

One sign of healthy development in plastics is the attempt to achieve optimum properties by combining several materials. In metals, alloying is of course an old practice. In plastics, several useful blends have already appeared, and more are on the way.

■ Modified styrenes, when cast, show a surprising versatility. Polystyrene itself, a thermoplastic that is usually injection molded, is known as a fairly brittle material. By "crosslinking" with polyesters, properties can be varied from extremely hard and rigid to tough and flexible. Advantages include excellent electrical properties and chemical resistance. But certain properties have to be sacrificed, depending on the degree of crosslinking—the hard types are rather brittle, the flexible types lack strength, the flame resistant types lose some transparency. . . . Up to now, uses were limited to high dielectric applications. Indications are for high strength applications in the future.

COPOLYMERS of synthetic rubber and resins—a chemical method of blending—are finding extremely wide application. Such mixtures are no longer new (see "Recent Developments in Plastics and Rubber," PRODUCT ENGINEERING, April 1947). Instead of relying on plasticizers which often "bleed out," the plastics industry decided to take advantage of the best properties of resins and rubbers. One of the most common types of synthetic rubber, GR-S, is itself a copolymer of about 75 parts of butadiene and 25 parts of styrene. By adding more styrene, the compound becomes less rubbery and more rigid. Principle is applied to combinations of GR-S and nitrile rubber with vinyl, phenolic and styrene resins.

■ Latest of these new copolymers to be announced are the "S-polymers," developed by the Standard Oil Company of New Jersey, blends of styrene with isobutylene (the main ingredient of "butyl" synthetic rubber). These resins are both elastic and thermoplastic; their tensile strength is about equal to polyvinyl chloride or cellulose acetate, with superior resistance to water vapor transmission. In film form they appear suitable for packaging and water resistant fabrics.

■ Blending with synthetic rubbers is also done to improve processing characteristics. Plasticizers are eliminated, mill time is decreased, and better extrusion and mold flow characteristics result. Two new modifications of butadiene-type rubbers were announced by the B. F. Goodrich Chemical Co. These compounds show increased building tack for laminated stock. One type is nonstaining.

■ Phenolic-modified synthetic rubbers are known to be particularly applicable to adhesives. (See article, "Industrial Adhesives," PRODUCT ENGINEERING, December 1947). Now, it imparts greater hardness, toughness and easier processing properties to GR-S, nitrile, neoprene, and even natural rubber. Tool handles made of these blends show increased resistance to aging and solvents. A host of rigid and semi-rigid products are anticipated.

COMBINATIONS of synthetics with other materials are not limited to physical or chemical blends. Often the most desirable combination of properties is achieved by alternating layers of plastics and metals, wood, or paper. Desirability of doing this was recognized early in the war, when aircraft construction became a problem. The result: Aircraft laminates, consisting of metallic skins bonded with synthetic adhesives to wood, or expanded plastics, for high strength-weight ratios. This "layer" idea of combination is appearing in new applications every day.

■ Combining plastics for improved performance, a new automobile radio antenna is insulated with polyethylene, with the whole wiring unit encased in a vinyl jacket. . . . Representing a volume saving of lead for covering cables, Bell Laboratories have developed a new cable consisting of a thin sheet of aluminum around paper-insulated wires, with an outer covering of polyethylene. The new cable will serve in local exchange areas, on pole lines and in underground conduits.

■ For refrigerators, postformed high pressure laminates are used in Australia. They form the cylindrical body of the refrigerator. Concentric laminates with air spaces between them comprise the thermal insulation. The cylindrical design is claimed to give increased storage space.

■ A relatively new phenolic resin to gain acceptance is furfural-phenol-formaldehyde (furfural is derived from the hulls of oats and other grains). A new laminating varnish made from this resin is claimed to produce lower cost laminates, equivalent in quality to conventional laminating varnishes.

In addition to equal speed of drying, cure, and final electrical properties, these varnishes have lower viscosity, enabling them to be shipped and used at higher solids content—thus giving significant solvent savings. Superior tensile strength and storage qualities are also claimed. However, the dark color may be a disadvantage in some uses.

PERHAPS the most universal application of plastics in combination with other materials, is in finishes and coatings. This use is not new—cellulose nitrate lacquers were first used in the 19th century. However, with the advent of thermosetting resins, hard durable coatings with specialized properties, such as electrical and solvent resistance, were possible. Principles developed in formulating finishes have now been carried over to adhesives, laminating varnishes, liners, casting sealants and impregnants.

■ For surface beauty, increased wear, and resistance to solvents, melamine resin-surfaced wood veneer, already used widely for table tops and other surfaces in bars, restaurants and retail stores, is being applied to home furniture. The beauty of the wood grain is enhanced by an illusion of "optical depth"; combined with the scratch-, alcohol-, and cigarette-resistance, a wide appeal to the housewife is forecast. . . . Melamine-surfaced subway maps, installed in New York City, are claimed to effect an initial saving of $72,000 by obviating frames and glass coverings. Less upkeep is also expected. The Navy is also applying this idea to maps; industry can use it to protect safety charts, steam-line diagrams, wiring and water systems.

■ Replacing metal foil, a new water vapor-resistant material is made by casting a 0.004 in. vinyl film on industrial paper. Tradenamed "Kastek V," it has already packaged gelatin desserts. Cost: About 10 cents per sq yd, compared with the 70 cent price for metal foil. Indications: For packaging feeds and other agricultural products.

■ Plastic lined chemical resistant steel pipe is now available. Originally made of vinylidene chloride, tradenamed Saran, Dow Chemical Company now extrudes a plasticized vinyl liner in the form of a 0.05 in. tube which is bonded to the inner surface of the metal pipe. Here the combination consists of the excellent chemical resistance of the plastic and the strength of the steel.

■ A bag-type liner of pliofilm (a type of rubber hydrochloride) in an insulated boxboard carton allows cool shipment without refrigeration. The combination of properties achieved is especially applicable to food. Live lobsters, precooled to 32 F are shipped for fifty hours without spoilage.

■ Phenolic resins have found wide acceptances as binders for mineral wool insulation. Growth of this use has resulted from industrial plant expansion and low-cost housing, where excellent insulation value of this material makes attics unnecessary.

■ A new sealing compound for aluminum refrigerators, prefabricated houses and truck bodies will soon be available in the form of a metallic filler—flexible plastic combination. Excellent adhesion to all metals and good weather resistance is claimed.

ALTHOUGH COMBINATIONS of plastics with other materials are important, use of solid plastics continue as the backbone of the plastics industry. Problems of molding as well as utilization of new molding powders are still uppermost in the minds of engineers.

■ War demands made ethyl cellulose a practical molding material. The impetus of the proximity fuse, making necessary a high impact water resistant "nose," had the plastics industry hopping. About five different thermoplastics were tried until ethyl cellulose was chosen for the purpose. This research resulted in improved molding powder and injection molding techniques.

■ Despite its fairly high price of 58 cents per lb, ethyl cellulose is now a "must" in applications where toughness at widely varying temperatures, combined with surface beauty, is required. Golf club heads, radio cabinets, piano parts, tool handles, refrigerator parts are typical examples. New markets are predicted because of its dimensional stability, fast molding cycles, and alkali resistance. Forecast for 1948 are an ethyl cellulose formulation to be troweled on for flooring, to spray on wood or concrete, and another spray to make wallpaper stainproof.

■ Phenolics, which are to plastics what steel is to metals, continue to be used widely. Molded as the cover of a redesigned one hp reversing switch, phenolics replaced a drawn steel cover. A superior product is claimed, with a 20 percent cost reduction. Several assembly operations were eliminated; housing insulation is now unnecessary; name-plate data is molded directly into the housing.

■ A new phenolic molding compound, developed during the war under the sponsorship of the National Advisory Committee for Aeronautics, is filled with macerated cotton fabric. The pieces of fabric are so large that the compound is practically in the "molded-laminated" class. Mechanical tests, recently reported by Professor William N. Findley, University of Illinois, show this mixture to have potentialities as a new engineering material, as soon as an economical molding method is worked out.

■ Automotive uses of molded plastics continue. According to a *Modern Plastics* survey, phenolic moldings, vinyl extrusions and acrylic decorative parts will increase in volume. The pros and cons

of laminated timing gears versus chain drives are being discussed in the automotive industry. Although the Stout car body—all glass-plastics—is not yet a reality, Kaiser-Frazer has purchased the patents. Rising cost of molds for steel stampings and expensive metal finishing operations are leading to serious consideration of glass-resin combinations for fenders and trunk doors.

■ Standard tolerances for injection moldings are much more rigid in the United States than they are in Great Britain, according to *British Plastics*.

CONVENTIONAL PRODUCTION METHODS in addition to compression and injection molding, include extrusion and machining. Often the techniques are combined, especially when products are made from thermoplastics. Sometimes conventional metalworking processes are modified in a special way, enabling for instance, plastics products to be fabricated rather than molded.

■ Centerless grinding is becoming important in plastics production. Stock removal may be as high as 0.040 in. per cut, compared with 0.005 to 0.010 in. for metals. Tolerances of the final piece run about 0.001 in., compared with an average of 0.0001 for metals. Method is used for machining laminates, and for making beads and knobs.

■ Extrusion is responsible for an important percentage of plastics production. Extruded cellulose acetate piping for cold water conveyance looks promising in cold climates. When water freezes, the plastic expands sufficiently to prevent cracking. . . . In California, similar piping is used for carrying home gas. Chief advantage is extreme ease of installation. . . . Boeing Stratocruiser has cellulose acetate butyrate tubing as water pipe, with polyvinyl chloride molded couplings and steel clamps. Replacing aluminum and stainless steel pipe, they save about 100 lb per plane, have better chemical inertness and resist low temperatures.

■ Polyethylene continues to become more widely applied. Restricted mainly to coaxial cable insulation about five years ago, and costing about one dollar per lb at that time, increased production has now reduced the price to 45 cents per lb. It is expected that this material will become one of the lowest priced plastics within a few years. Right now, it is taking the deep-freeze packaging industry by storm; bags of extruded polyethylene are heat-sealed at both ends for this purpose.

■ Use of plastics tooling has found wide acceptance in the aircraft industry. Lawrence Wittman, tool development engineer, Republic Aviation Corp., reported to ASME that low pressure molded glass-plastic laminates give a high degree of accuracy in the finished part. Indications are for jigs and fixtures in automotive and furniture industries.

■ Sheet thermoplastics, are being fabricated into draftsmen's aids. Polystyrene rulers with both edges sharply developed allow pen-and-ink ruling. A cellulose nitrate template is precision milled on a pantagraph machine—a departure from die-stamping of sheet stock. . . . Transparent polystyrene sheet makes the face of electrical instruments, having molded phenolic housings.

■ Engineers designing in plastics are becoming conscious of plasticity. *Plastics* (London) gives a relationship between plasticizer contention properties such as permanence, dimensional stability and inflammability. This is a valuable discussion for those dealing with cellulose acetate.

METALS

DESIGNERS must now contend with a new group of engineering materials. Developed originally during the war for jet engines, turbosuperchargers, and gas turbines, for service temperatures of 1,500 F and up, need for such materials was evident even in prewar days—as proved by studies on high pressure boiler and steam turbine parts. These new materials will have to be tested by entirely new means, to duplicate conditions of use—mainly at high temperatures, New uses, new materials, and high temperature tests are beginning to appear.

■ Jet engine exhaust cones made from high alloy steels show "hot spot" and workage because of poor heat conductivity. Warpage can be minimized by using stainless-clad copper. Copper diffuses heat evenly and rapidly.

■ Conventional metallic carbides have proved inadequate on 1,800 F gas turbine installations. However, a mixture of "rare" metallic carbides-cobalt and titanium carbide—has been fused. Combining properties of metals and ceramics a coined name, "Ceramals", has been suggested for these materials. At 1,800 to 2,000 F, one of these materials has a tensile strength of 15,000 to 21,000 psi. They cannot be machined, so must be made close to size and finished by grinding.

■ British engineers have developed a method for determining modulus of elasticity at elevated temperatures. It has long been known that the modulus drops slightly as temperature rises above room temperature, and that a temperature can be reached where the decrease is precipitous.

■ There is a relation between this behavior and creep characteristics: Boiler and furnace parts suddenly give way and aircraft bolts loosen. Of 25 types of steels investigated, all lost about 25 percent of their room temperature modulus at 1,100 F; ferritic steel moduli then dropped off rapidly, austenitic steel moduli continued a linear decrease to about 1,500 F and to 1,800 F showed only a moderately faster drop.

STAINLESS STEEL is settling down as an important engineering metal. Its properties and limitations are fast becoming known, and its uses are widening rapidly. The biggest single reason for the change in attitude toward

stainless steel is the fact that it can now be welded with ease. This new fabricating technique made possible the kitchen of the General Motors "Train of Tomorrow," equipped in stainless, as well as many new single-unit "short-order" stands, constructed with large quantities of stainless steel.

INITIAL ATTEMPTS to fabricate stainless by conventional welding methods proved unsatisfactory. Coating the electrode, to reduce oxide formation, worked for a limited number of alloys. The nation was at war and corrosion resistance of stainless steel was necessary for many marine applications. To satisfy this need, a new welding technique was devised. It consisted of shielding the joint from oxidation by surrounding electrode and weld area with an atmosphere of inert gas.

INERT GAS ARC WELDING, justifiably, is receiving much publicity. Helium was first used as the inert gas, but has been replaced by argon, for economic reasons. Helium is less expensive, per cu ft, than argon, but 2½ to 3 times as much helium is needed (see PRODUCT ENGINEERING, January 1948, page 131) for the same weld.

IN THE BEGINNING, conventional arc welding techniques were used. This was a good starting point, but much new knowledge is being developed.

- The arc, short in length and too sensitive for reproducibility has been stabilized by incorporating a high frequency unit in the circuit. High frequency current keeps the arc ionized, longer and less critical.

- No flux is required when welding with inert gas. There is no flux residue to cause corrosion of the finished part. Welded joints do not have to be cleaned or washed.

- Filler metal, when needed, is added from a separate, bare rod. This rod is fed into the arc struck between electrode and work. It can be of the same composition as the base metal, so no weakness is set up through dissimilarity.

- Tungsten electrodes are now in universal use with shielded arc welders. Tantalum electrodes tended to form a molten ball and fall off at very low currents; carbon electrodes burned away quickly and contaminated the welds, probably because of weakness in the binder material. Tungsten electrodes are virtually non-consumable and make no deposit.

WITH NEW USES for both new and old materials, what is the prospect of shortages in the future? Depending on the source of information, any desired answer can be obtained. Here are some specific examples.

- Aluminum sheet metal is available as roller-leveled flat sheet in widths of 30, 32, 36, and 48 in. with lengths of 96, 120 and 144 in; and as coiled sheet in widths of 24, 30, 32, 36 and 48 inches. Both forms can be had in thicknesses of 0.018, 0.020, 0.025, 0.032, 0.040, 0.051 and 0.064 in. Industry acceptance has been widespread and new orders are accepted with no delivery date.

- Steel scrap shortage is leading motor car manufacturers to consider replacing steel parts with aluminum (see PRODUCT ENGINEERING, December 1947, page 108). To maintain strength, aluminum parts may have to be 50 percent thicker, but in most cases the same dies can be used.

- Should the government continue to increase orders for military aircraft, a heavy drain on aluminum supplies will be felt. Industry people believe this possible. This could reverse the aluminum-for-sheet steel substitution.

- Copper, lead and zinc prices are expected to rise as long-range shortages of these metals are felt. Low-grade ore in inaccessible deposits will have to be used. Mining and refining costs will rise. Aluminum deposits are extensive enough to continue a downward price scale, as capacity for recovery increases.

- To form field windings for a new cyclotron at the University of Rochester, 1,700 50-ft lengths of 5/16 x 4 in. strips of aluminum were butt-welded. High conductivity aluminum was used because of copper scarcity. . . . Electro-magnetic coils for Columbia University's new cyclotron were formed from copper strips of 60 ft x 4 in. x 9/32 in. size. A continuous strip 13.5 miles long was made by controlled flash butt resistance welding the copper pieces. Is copper a scarce material?

IT IS ADMITTED that magnesium alloys are seldom comparable in cost to other metals, on a volume basis. However, redesign of parts frequently lowers final cost to a competitive value. Original price differential is expected to decrease when magnesium is rolled on continuous sheet mills. It was announced before a U. S. Senate investigating committee that magnesium alloy prices should decrease about five percent per year for the next five years.

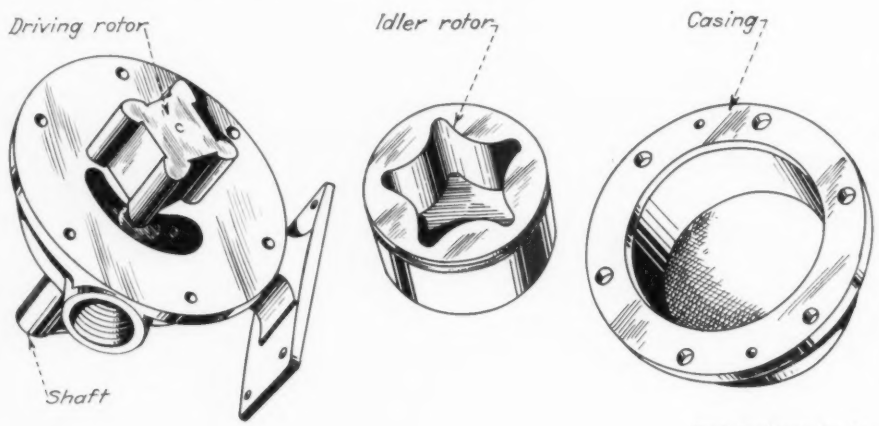
EVEN IN THIS PERIOD OF SHORTAGES, materials are being used solely because of their special properties. Two examples are worthy of note.

- Steel is clad on one or both sides with various metals for corrosion resistance. An oil refinery is now using a stainless steel cladded plate 2 in. thick to replace plates 4 in. thick. . . . For a long time many clad products were more expensive than solid plate especially when the cladding was more than 20 percent of the total thickness. Current prices show a substantial saving, at least for those cladded on one side only.

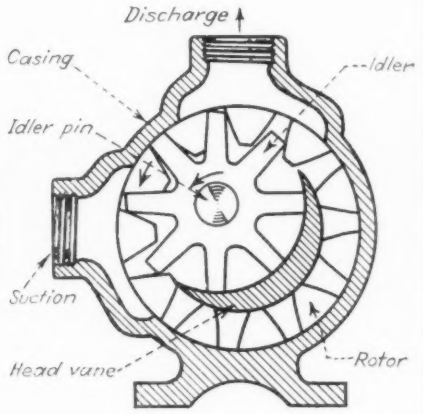
- Beryllium copper spring parts for a fractional horsepower motor control, a lighting switch, a refrigerator thermostat diaphragm and a small knife switch have been made with cost reduction over other materials. Because of its high fatigue strength, beryllium copper can be made with smaller sections. Operational characteristics of these springs are better than for others because of the uniformity in temper of the precipitation-hardened parts.

Designs and Operating Principles of

Types of pumps used to transfer liquids and to supply



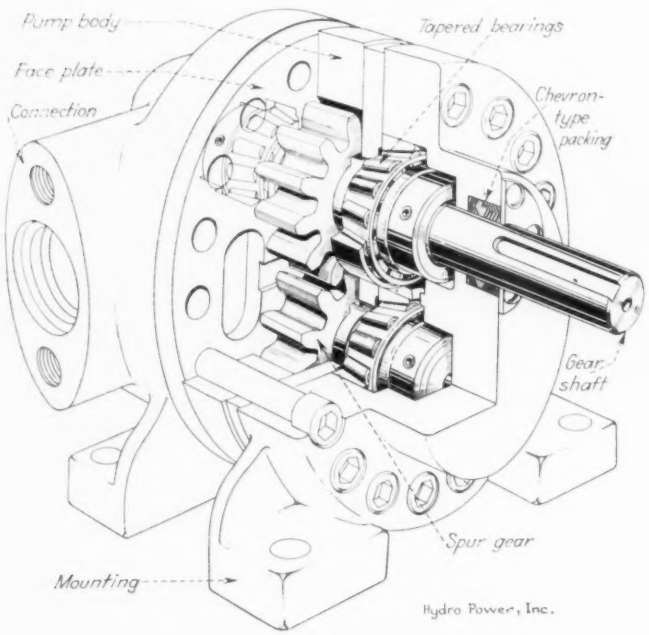
Paul Engineering Co.



Viking Pump Co.

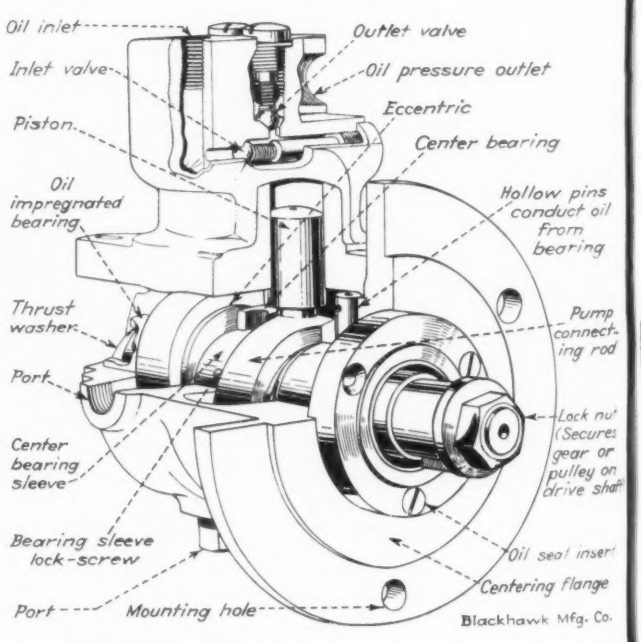
1 WITH BUT TWO MOVING PARTS, the rotors that turn in the same direction, the Sundberg Rotary Pump has reduced friction to a minimum. The rotors rotate against flexible synthetic rubber cushions that allow sand, grit and other abrasives to flow freely through the pump without damage. It is a positive displacement pump that develops a constant pressure and will deliver a uniform flow at any given speed. The pump is reversible and can be driven by a gasoline engine or electric motor. The rubber cushions withstand the action of oil, kerosene and gasoline and the pump operates at any angle. It has been used in circulating water systems, cutting tool coolant oil systems and general service applications.

2 PUMPING ACTION is produced by the meshing of the idler and rotor teeth in the Viking Rotary Pump. Idler is pin-mounted to the head. Rotor operates in either direction. Pump will not splash, foam, churn or cause pounding. Liquids of any viscosity, which do not contain grit, can be transferred by this pump made of combinations of iron and bronze parts.



Hydro Power, Inc.

5 THE GEAR SHAFTS of this hydraulic gear pump are mounted on tapered roller bearings that accurately position the gears, decrease end play and reduce wear to a minimum. The heavy duty construction of the Hydro-Power Gear Pump is designed for use with pressures up to 1,000 psi. These pumps are available with either single or double end shaft design and can be foot or flange mounted. The drive shaft entrance packing is constructed of oil resistant material. Gear shafts are made of hardened molybdenum steel.

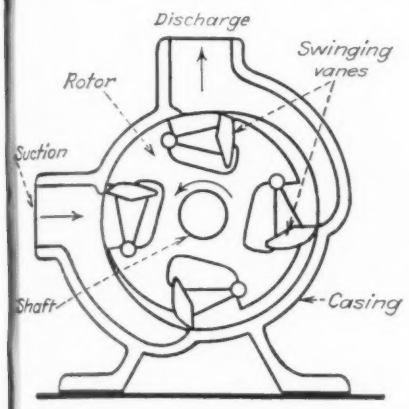


Blackhawk Mfg. Co.

6 THIS HIGH PRESSURE hydraulic pump has twin pistons that build pressures from 100 to 4,000 psi at speeds from 600 to 1,200 rev per minute. The Blackhawk P-104 can be used continuously at 900 rpm and 2,500 psi with 1.37 gpm delivered. Because it can be mounted at any angle, and because it is used with small oil lines, small diameter rams and compact valves, the P-104 is practical for building into new equipment. This pump contains a pressure adjusting valve that is factory set to by-pass at a predetermined pressure.

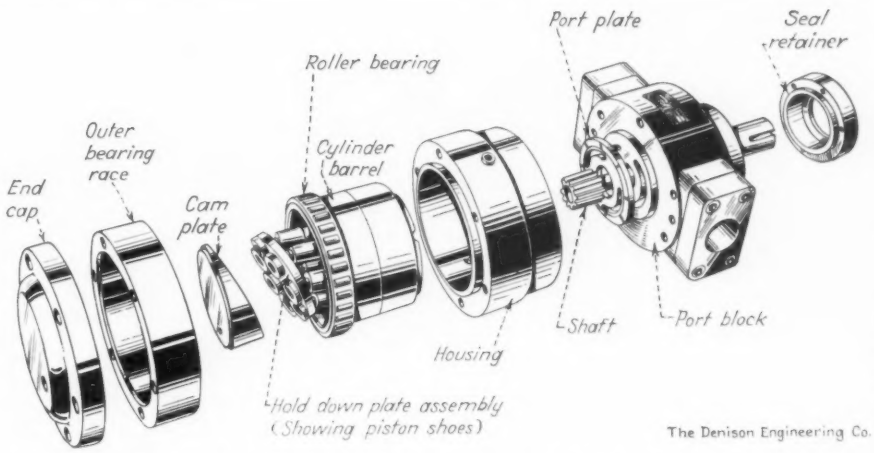
Typical Pumps Used in Industry—I

hydraulic power, with a discussion of design features and uses.



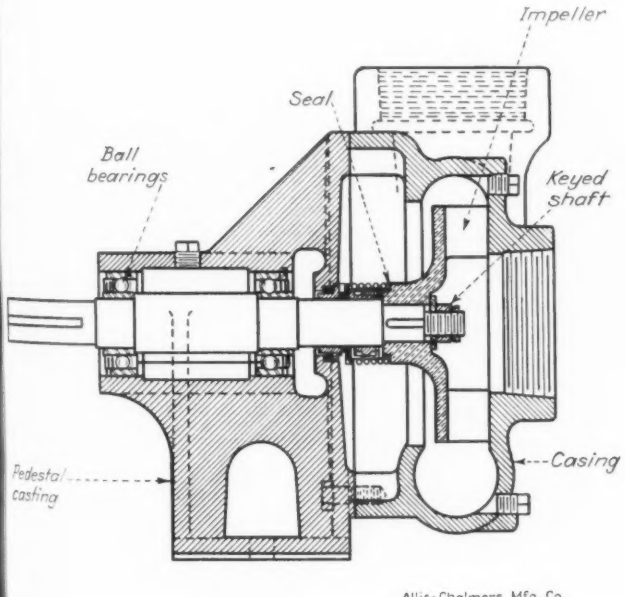
Blackmer Pump Co.

3 BASED on the swinging vane principle, the Blackmer Rotary Pump maintains its volumetric efficiency automatically. The action of the buckets, fitted loosely into recesses in the rotor, compensates for wear. In operation, the tip of the bucket is in light contact with the casing wall. Liquids are moved by sucking and pushing actions and are not churned or foamed.



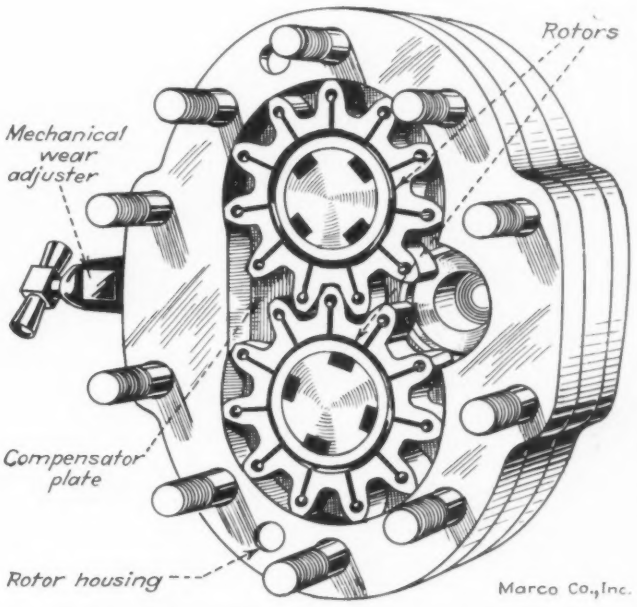
The Denison Engineering Co.

4 HIGH PRESSURE, high volume pumps of the axial piston, constant displacement type are rated at 3,500 psi for continuous duty operation; higher pressure is permissible for intermittent operation. A pressure-balanced piston shoe lubricates the cam plate and prevents direct contact between the shoe and cam plate. The use of the pressure balanced system removes the need for thrust bearings. The two-piece shaft absorbs deflection and minimizes bearing wear. The pump and electric driving motor are connected by a flexible coupling. The revolving cylinder barrel causes the axial reciprocation of the pumping pistons. The Denison 3500 Series pumps are only used to pump hydraulic fluids.



Allis-Chalmers Mfg. Co.

7 AS ITS NAME IMPLIES, the Pedrifugal pump is characterized by its pedestal mounting. The only fit, not a critical one, is between the pedestal casting and the casing. Positive alignment is obtained because the sealed ball bearings and the shaft are supported in the single casting. The 5-vaned, open, bronze impeller will move liquids with a considerable volume of solids. The pump is not for use with corrosive liquids. The five sizes of this pump, up to 500 gpm, are identical except for the impeller and the casing.



Marco Co., Inc.

8 USED TO TRANSFER, meter or proportion liquids of high or low viscosity, the Flowmaster Victor is a positive displacement gear pump. It is made of stainless metal or stainless steel with a stainless steel armored, automatic take-up, shaft seal of the single-gland type. Automatic wear control compensates for normal wear and maintains volumetric efficiency. The Victor will handle 5 to 300 gal per hour without churning or foaming. This pump needs no lubrication and operates against high or low pressure.

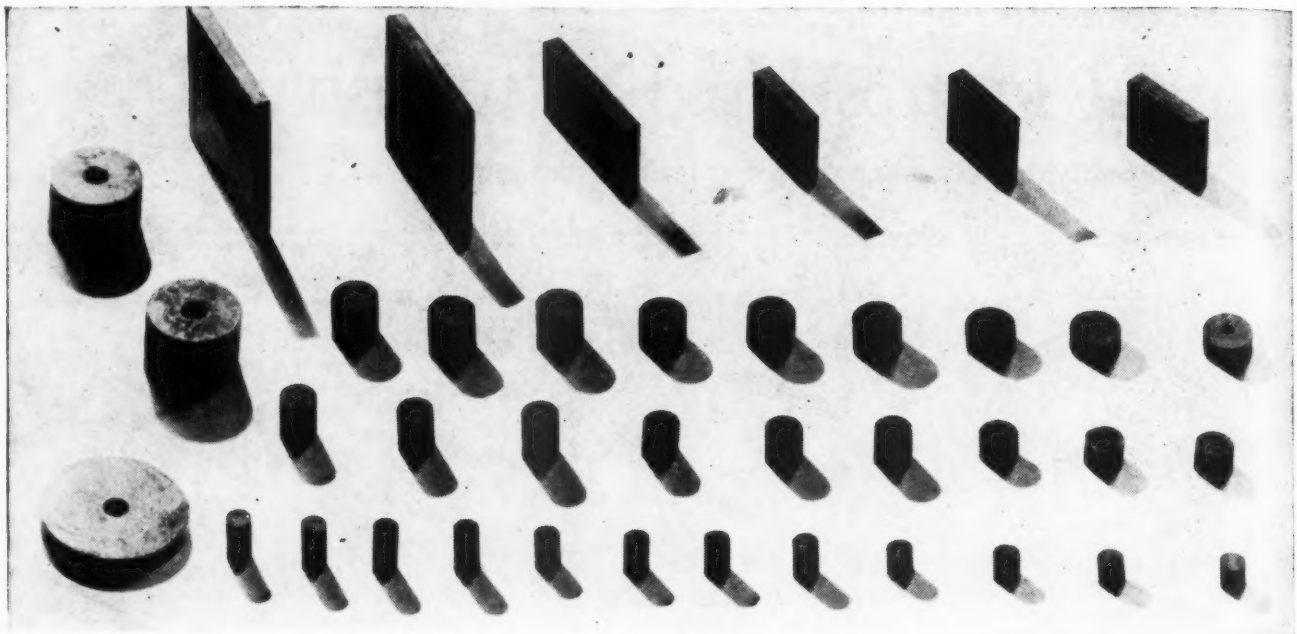


Fig. 1—Several types and sizes of permanent magnets made from sintered oxides. These sintered magnets have intense energy levels, high electrical resistivity, and strongly resist demagnetizing forces.

Permanent Magnets of

R. J. STUDDERS

Metallurgy Division, Chemical Department
General Electric Company

ALTHOUGH PERMANENT MAGNETS of sintered oxides have been known for some time, they have become available for industrial use only recently, largely because a pressing technique had to be developed, before they could be successfully produced. Powder metallurgy processes and equipment are utilized extensively. The raw materials are fine oxide powders, totally minus 200 mesh, and of the type and purity widely used in the ceramic industry.

A typical mix is prepared by accurately weighing 31.0 percent of red ferric oxide, Fe_2O_3, 43.0 percent of black magnetic ferrosoferric oxide, Fe_3O_4, and 26.0 percent of cobaltous oxide, CoO. These powders are intimately wet mixed in a porcelain jar mill for 36 hours. The powders are necessarily mixed wet, as the dry powders adhere readily to the surfaces of the mills and remain unmixed. The wet slurry is next dried at 160 C until most of the water has been removed. A cake of material results from the drying operation and this is reduced to a powder again by forcing the cake through a 40 mesh screen.

The powder may be pressed to shape at this stage, but in order to control the shrinkage occurring during the sintering operation, the loose screened powder is usually presintered at 600 C for 12 hr in air. The presintered powder is then ready to be pressed.

Because of the nature of the oxide materials the sintered density is primarily a function of the pressed density. A high pressed density would seem desirable but, as the oxide powders do not flow well under pressure, high compacting pressures only serve to laminate the pressed compacts, rendering them useless. On the other hand, too low a compacting pressure results in a low density material of poor magnetic quality. No pressing lubricant or binder is used in the pressing operation, but careful attention is paid to the pressure used, particle shape, and moisture content of the powders.

Pressing at 30 tons per sq in. may be done in any of the presses commonly used in powder metallurgy. Because of the pressure used and the abrasive nature of the material being pressed, ordinary steel dies are short lived. After four or five thousand pressings the die must be lapped and polished before continuing. Carboloy cemented tungsten carbide dies are preferred, as they resist the severe abrasion well.

The pressed compacts are fragile so that care must be used in handling them to prevent chipping and breakage. After being placed in stainless steel boats, they are sintered at 1,000 C for 3 hr in an air atmosphere. Protection against severe thermal shock is necessary during the sintering operations. With proper regulation of the presintering operation, the linear shrinkage during sintering can be reduced to 1.5 to 2 percent. A group of sintered oxide magnets is shown in Fig. 1.

Inserts can be cemented in the sintered magnets, using holes cored during the pressing operation. Complicated shapes, such as multi-poled rotors may be more easily manufactured in segments and cemented together later.

Similar to the more widely known Alnico 5, the permanent magnet material known as Vectolite is cooled through a region slightly below its Curie temperature in a magnetic field. A field strength of at least 1,000 oersteds is used. This treatment imparts a preferred axis of magnetization to the material, which is parallel to the axis of the magnetic field. When magnetized along the preferred axis, the material exhibits much higher magnetic properties than found along any other axis in the material. To illustrate this point: Curve 1 of Fig. 2 shows a typical demagnetization and available energy curve, taken with the specimen magnetized along its preferred axis. Curve 3 shows the demagnetization and available energy of

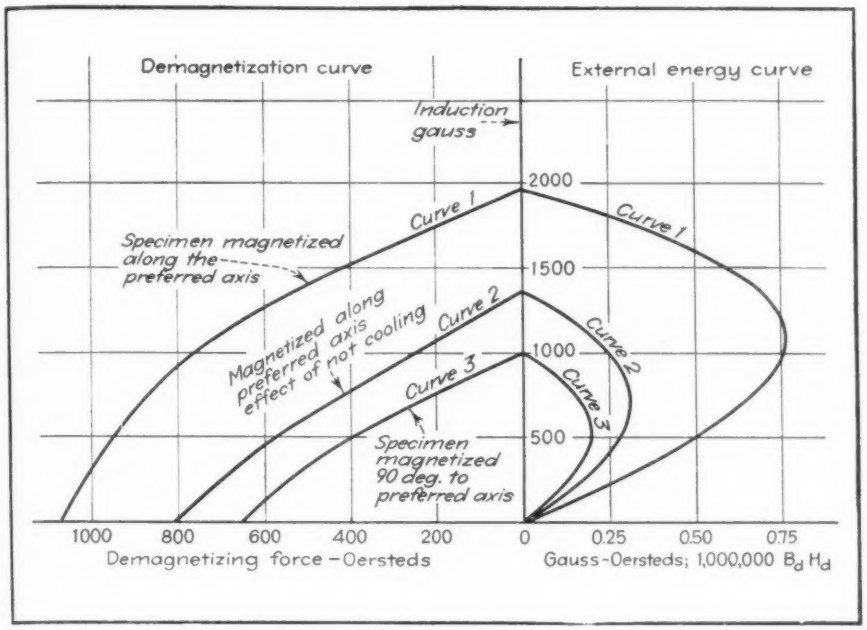


Fig. 2—Demagnetization and external energy curves of specimens magnetized along preferred axis, perpendicular to preferred axis, and specimen not cooled in magnetic field.

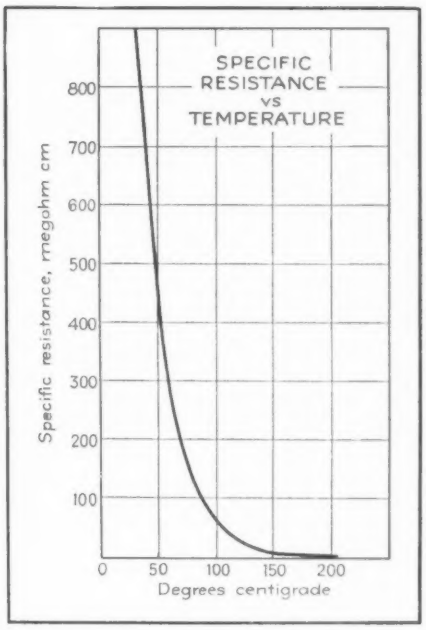


Fig. 3—Variation of specific resistance of sintered oxide magnet with temperature.

Sintered Oxides

the same specimen, but taken along an axis 90 deg to the preferred axis. Curve 2 is a demagnetization and available energy curve for a specimen of sintered oxide magnet not cooled through the region below its Curie temperature in a magnetic field. From curves 1 and 2, it may be seen that the cooling in a magnetic field from elevated temperatures improves the residual induction, B_r, by some 45 percent, the coercive force by 30 percent and most important the maximum available energy by 150 percent.

Physical and Electrical Properties

Differing from ordinary magnet materials, magnets of sintered oxides are semi-conductor's and possess high electrical resistivity, at room temperature. Although resistivity will be influenced somewhat by porosity, impurities, type of binder and other factors, it is considerably higher than the resistivities recorded for other magnet materials. Thus, in the presence of high frequency fields, the sintered oxide magnet may be used to supply a magnetic field without interference of eddy current effects predominant in metallic materials. Because of this property, Vectolite has found many applications in high frequency work. In permanent magnet applications where the practice has been to insulate the magnet material from its component electrical circuit, the sintered oxide magnet can be used without insulation. Fig. 3 is a curve prepared from data taken with a 1,000 v megger on a specimen of sintered Vectolite, previously dried at 200 C. At room temperature this material appears to be practically an electric insulator.

Vectolite has a specific gravity of 3.15, less than half that of any of the metallic magnet materials. Thus the demagnetization curve of this sintered oxide magnet material and the energy available compares more favorably with metallic magnet materials when made on a unit weight rather than on a unit volume basis. On the list of available permanent magnet materials, only Alnico 5, and modifications of it, show greater energy available than Vectolite per unit weight of material. This is significant since permanent magnets are usually priced on weight rather than on volume.

Magnetic Properties and Design Data

Vectolite is anisotropic in nature. The design data, Table I, gives properties of the material magnetized in its preferred direction. This anisotropic nature, while allowing the material to make more energy available, also imposes some limitations on its use by the designer. In manufacture, it is difficult to impart maximum properties along multi-directional flux paths by cooling in a magnetic field from elevated temperatures. Designs that must have abrupt directional changes in the flux paths through the magnet therefore should be avoided. Such

Table I—Typical Properties of Sintered Oxide Magnets Along the Preferred Direction of Magnetization

Magnetizing force for saturation, oersteds	3,500
B_s, Saturation induction gausses	2,200
B_r, Residual induction, gausses (remanence)	1,900
H_c, Coercive force, oersteds	1,000
H_{ci}, Intrinsic coercive force, oersteds	1,150
(B_dH_d) max. Maximum available energy, gauss-oersteds	750,000
at B, gausses	1,000
Resistivity, Megohm cm at room temperature	See Fig. 2
Coef. of linear expansion, 20 to 300 C	8.5×10^{-6}
Specific gravity, grams per cu cm	3.15
Curie temperature, C	540
Transverse modulus of rupture, psi	3,000
Max operating temperatures, C	200

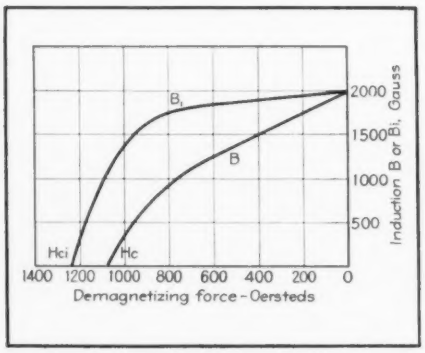


Fig. 4—Unlike most magnet materials the coercive force of sintered oxide magnet is much higher than the coercive force.

magnets are expensive to manufacture. Care should also be taken to assure that the final magnetization before use is in the preferred direction through the magnet. The order of magnitude of the loss of magnetic energy that would result from magnetization in a direction other than the preferred direction may be estimated by a comparison of Curves 1 and 3 of Fig.2. These design limitations exist for all anisotropic permanent magnet materials.

A magnetizing force of at least 3,500 oersteds is necessary to saturate the sintered oxide material. Curve 1 of Fig. 2, which is a typical demagnetization and external energy curve, indicates that Vectolite has a high coercive force, H_c, 1,075 oersteds, and a relatively low residual induction, B_r, 1,950 gauss with a maximum energy product of 775,000 gauss oersteds. Therefore, relative to the more common magnet materials a shorter magnet of larger cross-section will be needed to supply a given amount of flux. In common with all permanent magnet materials, the magnetic characteristics of Vectolite may be varied considerably by the method of manufacture.

In most commercial magnetic materials, the coercive force H_c and the intrinsic coercive force H_{ci}, are nearly the same. However, with material such as Vectolite, there is a considerable difference in these values of coercive force and the intrinsic coercive force of the magnet is a more accurate measure of the resistance to demagnetization. As shown by the curves of Fig. 4, the intrinsic coercive force is greater by some 160 oersteds. Data from an experimental determination of a demagnetization curve of a specimen of Vectolite, with some of the minor hysteresis loops, are shown in Fig. 5. For practical purposes the average slope of these minor loops is equal to the incremental permeability for the material. This quantity is important to the designer because the incremental permeability of a permanent magnet material is a measure of the degree of its stability against demagnetizing influences. The smaller the value of the incremental permeability the smaller the flux changes will be under demagnetizing influences. As may be seen from the graph, the incremental permeability is approximately one for Vectolite.

Flux density in the neutral section of a straight bar magnet plotted against the ratio of magnet length to its equivalent diameter is shown as a curve in Fig. 6. A curve of this type is used by many designers to predict the performance of a permanent magnet. This specimen possessed a residual induction, B_r, of 1,970 gausses, a coercive force, H_c, of 1,080 oersteds, and a maximum energy product, (B_dH_d) max. of 790,000 gauss oersteds at a flux density, B, of 1,150 gausses.

Heat, Vibration and Aging

To determine the maximum operating temperature of Vectolite and the effects of heat on it, a series of temperature tests were conducted as follows: Fully magnetized test bars after being heated to 100 C and cooled to room temperature, showed less than 0.6 percent loss in remanence. On successive cycles of heating to 100 C no appreciable remanence change was detected. Heating to 200 C and then cooling to room temperature, caused an initial loss in remanence of 2.4 percent; successive cycles to 200 C caused no further remanence change.

On initially heating a fully magnetized specimen to 300 C a 28 percent loss in remanence was detected on cooling to room temperature. This large loss is attributed to the destruction of the preferential alignment given the material by originally cooling it in a magnetic field. The Curie temperature for the sintered oxide magnet has been found to be about 540 C, varying with impurity content.

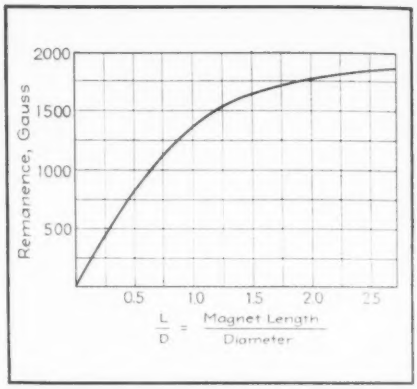


Fig. 6—Variation of the flux density with the ratio of length to diameter of a straight bar magnet of sintered oxide.

From these tests the conclusion is that Vectolite may be safely operated to temperatures of 200 C. Reasonable stability may be expected even if the magnet is heated a few times slightly above this maximum operating temperatures. Cements that set below 200 C or resin binders that can be cured below 200 C may be safely used with the sintered magnet without destroying its magnetic properties. No appreciable change in its demagnetization curve after long periods of time, and little remanence change upon repeated heatings to 200 C indicate that the material is structurally stable in this temperature range.

To test the effects of vibration on Vectolite, fully magnetized test bars were vibrated at frequencies from 10 to 50 cycles per sec with total displacements from 0.005 to 0.100 in. for as long as 90 min. Within the error of measurement no change in remanence of the test bars could be detected.

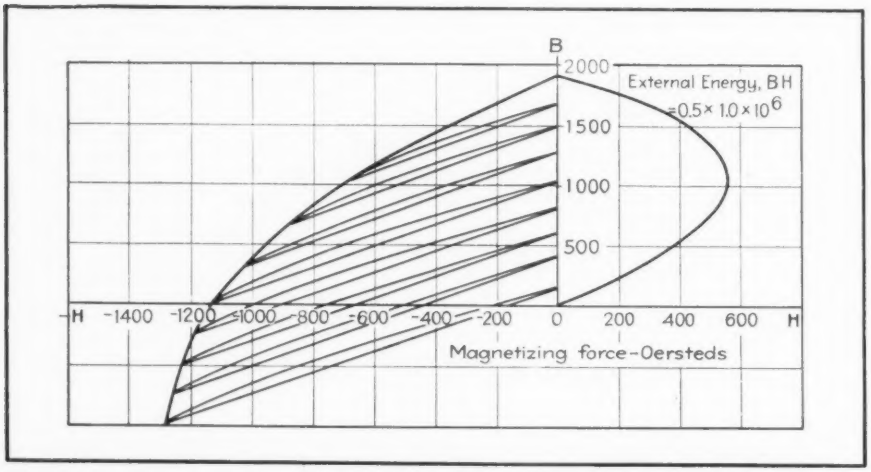
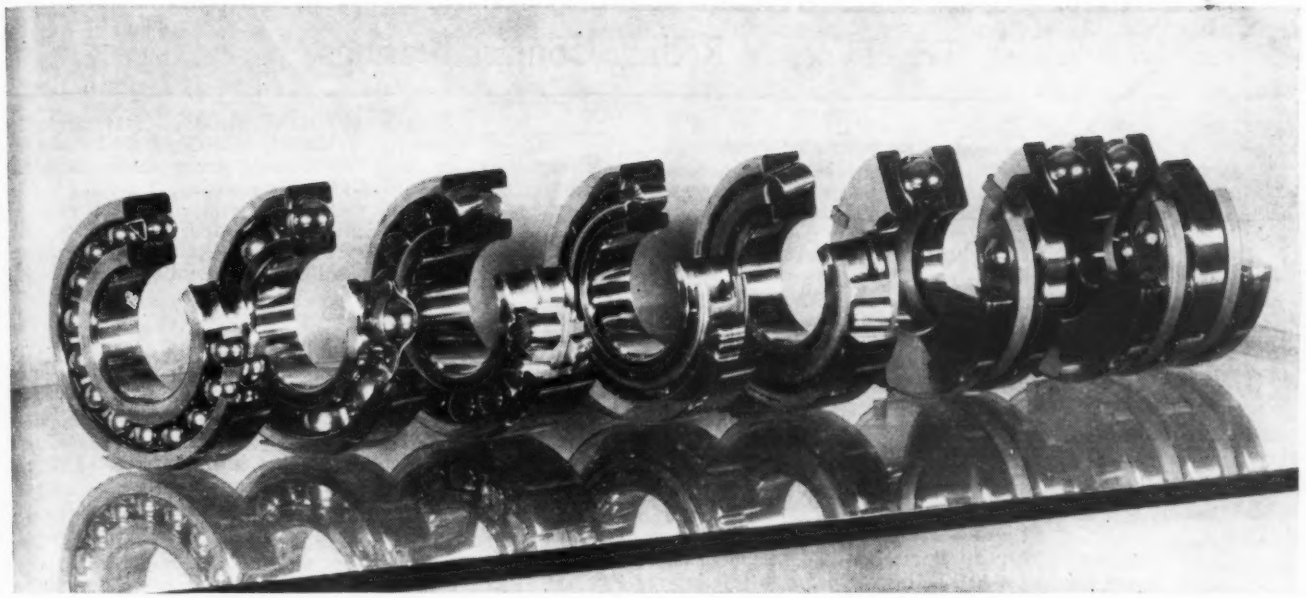


Fig. 5—Minor hysteresis loops from experimental determination establish an incremental permeability of about one. Such magnetic material is relatively difficult to demagnetize.



From left to right: self-aligning ball bearing; deep groove ball bearing; spherical roller bearing; cylindrical roller bearing; tapered roller bearing; thrust ball bearing, and two-direction thrust ball bearing. There are many variations of these basic types of bearings.

Ball and Roller Bearings

- Relative merits of rolling contact bearing types for various operating conditions.
- Considerations of misalignment, friction, deflection, lubrication, and operating speed that affect the choice of bearing.

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BEARINGS ARE USUALLY CHOSEN on the basis of their fatigue life. This is the number of revolutions, or hours of operation at some given speed, that the bearings are expected to run before the first signs of fatigue spalling or flaking appear. Other types of failure such as lubrication, abrasion or wear, pitting, and corrosion are usually regarded as preventable and therefore are not considered in estimating the probable bearing life.

An important factor in the selection of a bearing is the degree of reliability required from the machine. If the machine is to be used only intermittently and if replacement of parts can easily be made during down periods, then a bearing with a relatively short life can be selected. Sometimes a short life must be accepted because space limitations prohibit the use of a larger bearing, although this condition can often be avoided by considering the bearing requirements early in the design development. When a bearing with a short life is selected, the mounting should be designed to facilitate bearing replacement. The ease and speed with which anti-friction bearings can be replaced, without fitting or running-in period, constitute one of their greatest advantages.

If the failure of a bearing involves possible loss of life or major financial or production loss, then considerably more importance is placed on reliability. For example, the additional insurance against the possibility of the breakdown of a key machine may make the choice of a larger and more expensive bearing both wise and economical. Bearing costs should be viewed from the broad point of view of the total cost of replacement.

Availability is another important factor to consider. This includes not only availability of the bearing when the machine is built but also some insurance that a replacement can be quickly obtained if failure occurs.

Availability and cost considerations are two of the strongest reasons why standard bearings should be used in preference to special bearings whenever possible. Standard bearings, which are interchangeable, are manufactured by a number of competing companies. Volume production and competition keep the prices low and assure ready availability of replacement bearings. Special bearings, on the other hand, are comparatively costly and not readily replaced since they are manufactured only on order.

While many bearing types are designed to carry both radial and thrust loads, heavy thrust loads at normal speeds are usually best carried by separate thrust bearings. At high speed centrifugal force tends to cause a phenomenon known as "wedging" in ball thrust bearings, see Fig. 1, so that under these conditions angular contact

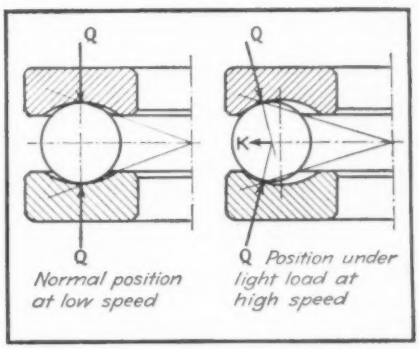
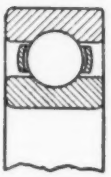


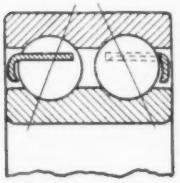
Fig. 1—Wedging: the position of the ball high on the raceway shoulders increases friction and results in decreased life.

Ten Types of Rolling Contact Bearings



SINGLE ROW DEEP GROOVE BALL BEARING. Will sustain a radial load and a substantial thrust load in either direction, even at very high speeds. This advantage results from the intimate contact between the balls and the deep groove. Careful alignment between shaft and bearing housing is essential.

Applications: Electric motors, automobiles, conveyor rolls, aircraft accessory drives.



DOUBLE ROW BALL BEARING. Grooves are so positioned that the load lines through the balls have an outwardly converging contact angle. Has a lower axial displacement than the single row design, substantial thrust capacity in either direction, and high radial capacity because of the two rows of balls.

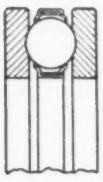
Applications: Gear reduction units, transmission shafts, starters, generators, auxiliary aircraft equipment.

ANGULAR CONTACT BALL BEARING. Supports a heavy thrust load in one direction, sometimes combined with a moderate radial load. When sides are flush ground, can be mounted in tandem for constant thrust in one direction; in pairs face-to-face or back-to-back for combined loads.

Applications: Worm drives, pumps, machine tool spindles, centrifugals, superchargers.

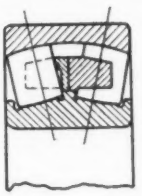
SELF-ALIGNING BALL BEARING. Adjusts misalignment resulting from errors in the mounting or shaft deflection, without loss of capacity. Does not exert any bending influence on the shaft, essential requirement for extreme accuracy at high speeds. Recommended for radial loads and moderate thrust loads in either direction.

Applications: Woodworking machines, small hammer mills, fans, centrifugals, pillow blocks.



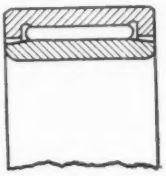
BALL THRUST BEARING. For thrust load in one direction only. Load line through the balls is parallel to shaft axis, resulting in high thrust capacity and minimum axial deflection. Flat seats on the rings are preferred where the load is heavy or where close axial postioning of the shaft is essential. Should not be used for high speeds under light loads.

Applications: Crane hooks, machine tool spindles.



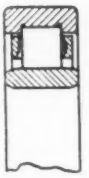
SPHERICAL ROLLER BEARING. Has unexcelled capacity. Inherently self-aligning. In addition to heavy radial loads, heavy thrust loads may be carried in either direction.

Applications: Steel mill equipment, crushers, railroad journal boxes, paper mills, rubber mills, fans, blowers, pumps, compressors, hammer mills, oil field equipment, pillow blocks.



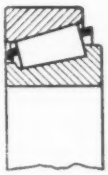
NEEDLE BEARING. Carries heavy radial loads without taking up a large space radially. Since the rollers cannot be flange guided this bearing has rather high friction and operates best when the load is relieved at least once per revolution.

Applications: Crankpins, wristpins, cam rollers, aircraft controls and landing gears.



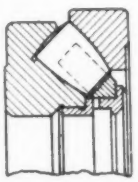
CYLINDRICAL ROLLER BEARING. Has high radial capacity and provides accurate guiding of the rollers, resulting in a close approach to true rolling. Consequent low friction permits operation at high speed. Some types allow only a limited free axial movement of the shaft. All are easy to dismount.

Applications: Traction motors, transmission shafts, machine tool spindles, aircraft engines, gas turbines.



SINGLE ROW TAPERED ROLLER BEARING. Carries heavy radial loads when opposed to another bearing taking the induced thrust load. Also can carry heavy one-directional thrust or combined load. Requires adjustment of internal clearance. Steep-angle type is for predominantly thrust loads; multi-row types carry heavy loads in any direction.

Applications: Automobiles, mine cars, steel mill equipment, journal boxes, pumps, gear drives.



SPHERICAL ROLLER THRUST BEARING. Compact bearing for heavy thrust loads. Especially adaptable to such applications as worm drive, where minimum bearing centers are an advantage. Self-aligning and capable of sustained high speeds at low operating temperatures.

Applications: Steel mill equipment, gyratory crushers, pumps, turntables, water turbines.

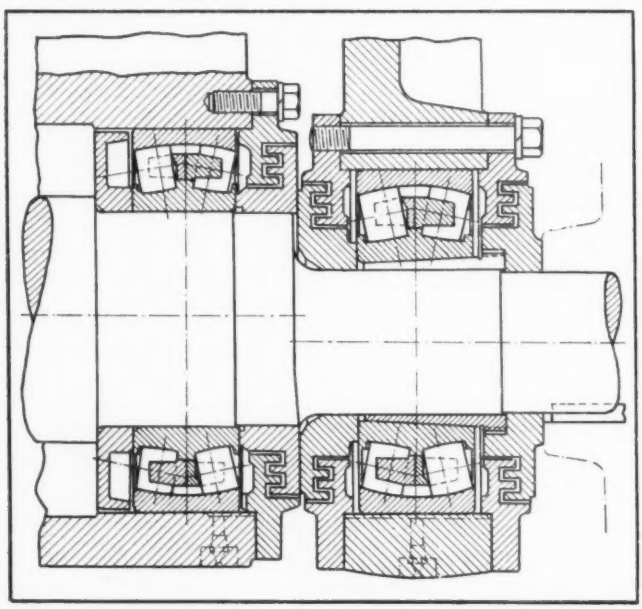


Fig. 2—Bearings in a jaw crusher. An example where both the high capacity and the self-aligning qualities of spherical roller bearings are of major importance in an installation.

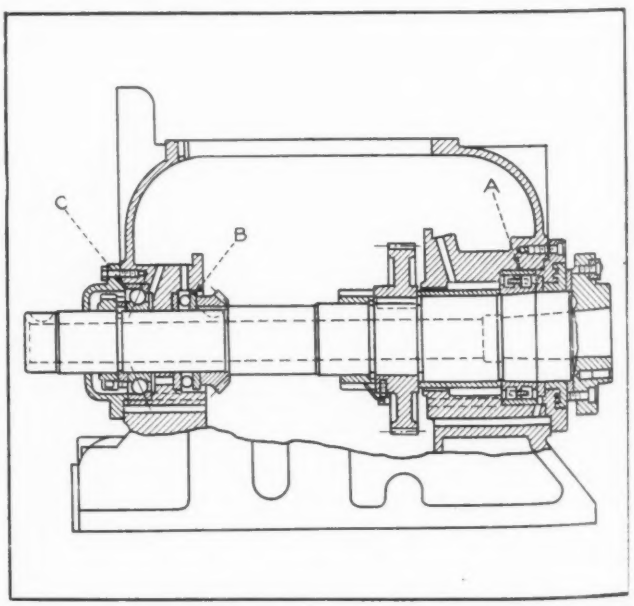


Fig. 3—Automatic lathe spindle design, a bearing arrangement giving maximum spindle rigidity under heavy combined loads. Cylindrical bearing takes the heavy radial load.

or deep groove ball bearings are usually more satisfactory.

Ball bearings are usually the most economical choice in the smaller sizes while in the larger sizes, especially if shock and impact loads are present as in Fig. 2, roller bearings have a considerable advantage.

Application of these principles is shown, Fig. 3, in an automatic lathe. The cylindrical roller bearing takes, with minimum deflection, the heavy radial load on the bearing nearest the workpiece. The ball thrust bearing carries the working thrust load, while the angular contact ball bearing takes a light radial load and acts to oppose the ball thrust bearing or to take thrust in the opposite direction.

Misalignment

If a bearing is misaligned any considerable amount, self-aligning bearings have definite advantages over rigid bearings, since they can take several degrees of initial misalignment without loss of capacity. Rigid types of bearings vary considerably in their ability to take misalignment. Roller bearings, which have line contact at both raceways, as in cylindrical roller and tapered roller types, are especially sensitive to misalignment. This sensitivity can be somewhat reduced by crowning the rollers or raceways. Deep groove and angular contact ball bearings, while not quite as sensitive as line contact bearings, lose some capacity if misaligned more than about $\frac{1}{4}$ degree. The jaw crusher in Fig. 2 is an example in which high capacity and self-aligning qualities are required.

Moment loads, or couples, can be carried by a single rigid type bearing but not by a single self-aligning bearing. The usual practice is to carry moment loads by two bearings mounted as far apart on the shaft as possible.

Deflection

Some internal radial clearance is generally left in bearing parts after mounting on the shaft and in the housing. When a radial load acts on the bearing, the shaft takes up the internal clearance and, in addition, moves an amount equal to the elastic deflection at the contact between the most heavily loaded ball or roller and the raceways of the bearing rings. Total movement of the bearing under load is usually only a few thousandths of an inch.

If the load is chiefly thrust, the shaft moves axially an amount equal to the axial looseness plus the axial elastic deflection at the bearing contact points. Axial movement is somewhat larger than radial movement for radial bearings, and is sufficient to cause trouble in some applications; for example, precision machine tools.

Radial and axial deflection often can be reduced to a negligible amount by mounting two angular contact bearings opposed and preloaded. This requires that bearing end faces be flush ground so that when mounted with the proper fit and under no external load, the two bearings press axially against each other with a certain predetermined force. The initial internal clearance of the bearings is zero and the elastic deflection under load is substantially reduced. Fig. 4 shows the arrangement and typical performance curves.

If extremely close control of the bearing running accuracy is required, super precision bearings should be used. These precision tolerance bearings are standard types produced in quantity under minute tolerances of eccentricity, parallelism of sides and grooves, and side runout with the bore, as established by the Annular Bearing Engineers' Committee. Although not regarded as special bearings, the necessity of producing them to closer tolerances than normal makes them more costly than standard tolerance bearings. The use of precision bearings is economically justified only when the running accuracy of the machine is equally closely controlled, and when that high a degree of precision is actually required.

Friction

In some precision instruments, consideration must be given to the friction in the bearing. For general applications the friction is negligible, which is a marked advantage of ball and roller bearings over other types. The slight amount of friction present varies with load and speed. A method of computing its value will be included in the second article of this series.

In addition to bearing friction, the friction of rubbing type seals must be considered where friction loss can

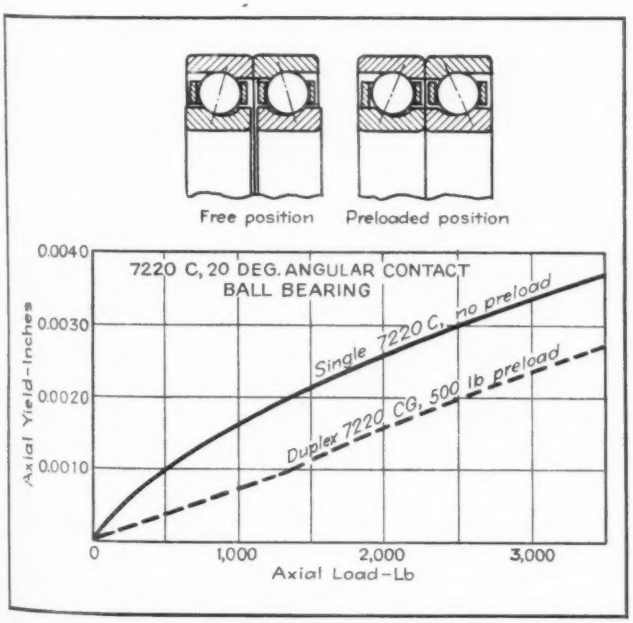


Fig. 4—Comparative axial deflection curves under thrust loads for a regular angular contact bearing and for a pair of preloaded bearings mounted opposed.

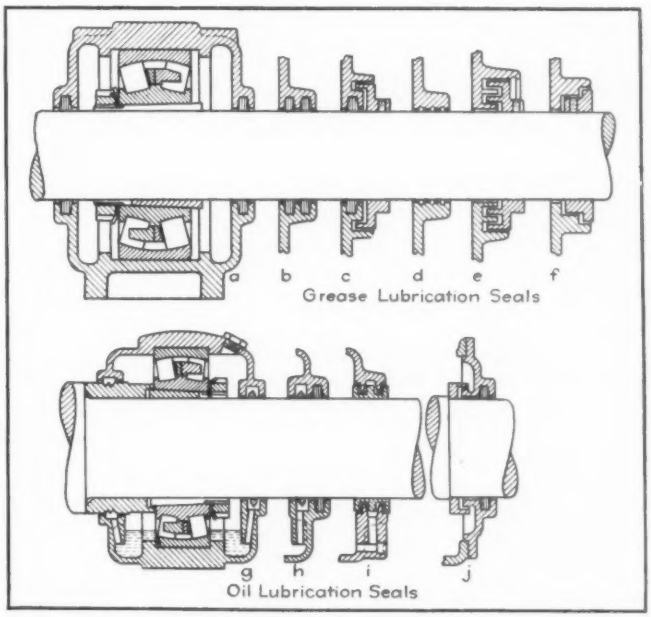


Fig. 5—Seals for bearing lubricants. Designs *c*, *e*, *f*, *i*, and *j* are labyrinth seals, although *c* and *j* also contain friction seal elements. Friction in rubbing type seals is much larger than bearing friction.

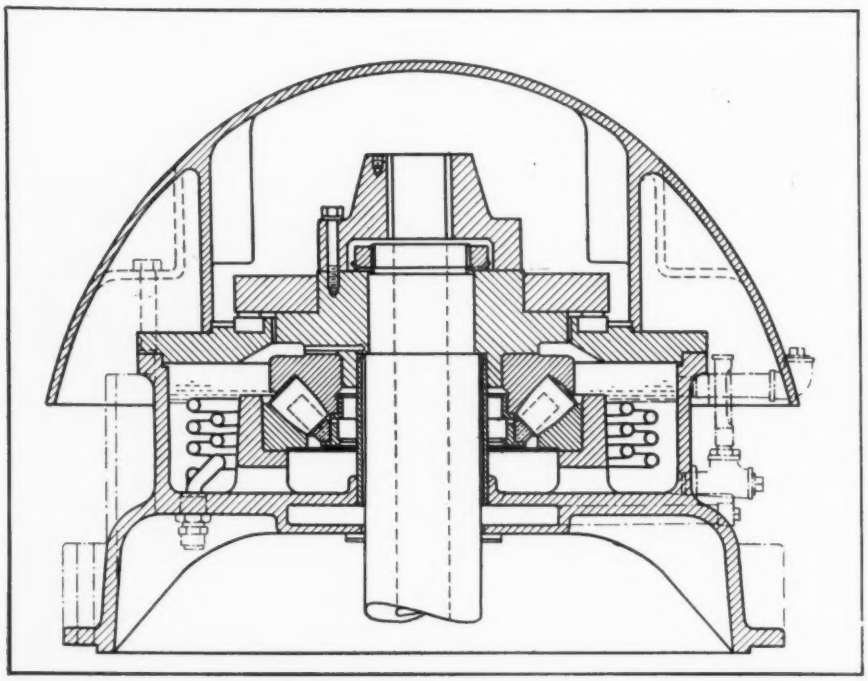


Fig. 6—A heavy vertical load acts on this self-aligning spherical roller thrust bearing, which is spring opposed loaded to prevent the rings from separating when the load is removed. The oil is pumped up through the bearing by centrifugal force and returned to the lower bearing bore through the holes seen in the lower ring support piece.

cause trouble . Rubbing type seal friction is normally much greater than bearing friction. Minimum seal friction can be obtained with nonrubbing labyrinth type seals, where these are possible. These seals consist of a rotating and a stationary ring that have mating flanges so designed that the two rings fit closely over a wide area, but without actual contact. The friction of this type of seal is usually less than the friction of the bearing. See Fig. 5 and also "Ball and Roller Bearing Seals," PRODUCT ENGINEERING, April 1947, p 103, for examples.

LUBRICATION

The choice of lubricant may have great effect on bearing friction and sometimes even limit the choice of bearing type when the heat of friction is not dissipated rapidly enough. In any rolling bearing there is some incidental sliding within the contact areas between rolling elements and raceways, between cage and rolling elements and, in guided roller bearings, between the guiding flange and the roller ends. This is the reason lubrication is necessary.

Grease is a satisfactory lubricant at normal operating temperatures. It has the advantage that the seal usually can have a simple design since the grease itself improves the seal efficiency. The housing should not be filled more than half full of grease; a greater amount causes excessive churning and friction. Any provision for relubrication should insure that new grease is injected at a point adjacent to the raceways and in such a way that the old grease is forced away from the bearing and, if necessary, removed.

Oil lubrication can be used at low speeds and low operating temperatures if more convenient. At high speeds and high operating temperatures the use of oil is mandatory. Oil level lubrication, as exemplified on the deep well pump in Fig. 6, is usually most convenient, providing the operating temperature is not too great. Practical limits are set by the conditions that the oil must be sufficiently fluid when the machine has stopped operation for some time and that the oil should have a viscosity of at least 70 sec Saybolt at operating temperature. The oil level should be about even with the center of the lowermost ball or roller when the bearing is stationary.

These operating conditions are satisfactory up to certain speeds, provided that the bearing is not operating near a heat source. The limiting speeds, dn values, which should not be exceeded without special attention to lubricating conditions, are given in Table 1 for various types of bearings. In reality no sharply defined speed limit exists; but if the limits tabulated are to be exceeded, a bearing engineer should be consulted.

While high speed applications often require special analysis, two general types of high speed lubrication are in frequent use. One, exemplified by the oil mist lubricator, is used where only the heat of bearing friction is encountered. By reducing friction to a minimum this method attempts to keep heat production low enough to be dissipated easily. The other method, using circulating oil or cooling coils, is advisable if the bearing operates near heat sources or if the bearing speed is so high that heat from bearing friction cannot be adequately dissipated by normal radiation.

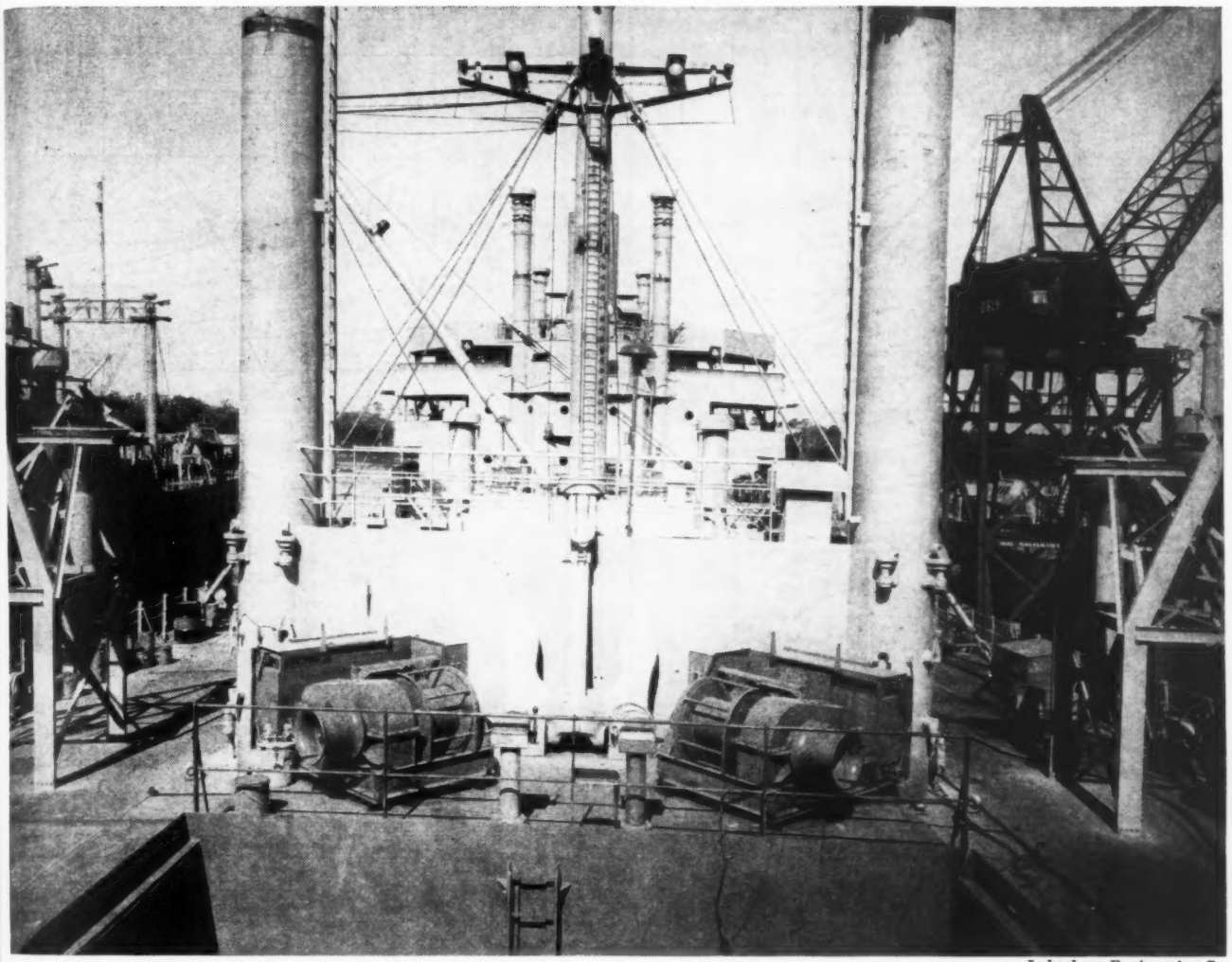
Ease of assembly, disassembly, and maintenance is another factor in the choice of bearing type. The designer must insure that the bearing mounting can be assembled and disassembled easily and that the bearing is adequately protected from water, dust, and other abrasive or corrosive materials. Provision must be made for adequate relubrication and cleaning.

In addition to these major considerations there are many special problems. Axial motion of the shaft from temperature expansion or the eccentric action of crank motions are problems that require the advice of a qualified bearing specialist. The last article of this series will discuss methods of computing bearing size.

Table 1—Limiting Speeds for Normal Lubrication Conditions

d = bore of the bearing in millimeters n = rpm

Type of Bearing	Cage Type	dn Value	
		Grease	Oil Level
Self-aligning ball	Pressed Steel	200,000	300,000
Single row deep groove	Pressed Steel	200,000	300,000
Single row deep groove	Pressed Bronze	200,000	400,000
Double row ball	Pressed Steel	150,000	225,000
Angular contact ball	Bronze	200,000	300,000
Cylindrical roller	Bronze	150,000	300,000
Spherical roller	Bronze	100,000	200,000
Thrust ball bearings	Pressed Steel	150,000	225,000



Lakeshore Engineering Co.

CARGO VESSELS can be a-c equipped and retain all advantages of d-c deck machinery by using the adjustable voltage system for hoists.

Adjustable-Voltage Control System

Operating characteristics of a newly developed a-c powered adjustable-voltage scheme for driving machines such as cranes that hoist and lower overhauling loads. Performance compared with conventional constant voltage d-c system.

J. E. JONES

Supervising Engineer, Cutler-Hammer, Inc.

OPERATING CHARACTERISTICS of a newly devised a-c powered adjustable-voltage scheme provide more precise performance than the constant voltage d-c system commonly used for hoisting and lowering heavy overhauling loads. The adjustable-voltage system has the desirable trait of drooping speed with load in either direction of travel. Compared with the d-c system, in the 25 to 50 hp range the a-c drive is only about one-third bigger and heavier. This includes the hoist motor, motor-generator set, brake, control panel and master controller. Because of the overall operating efficiency, the m-g set is relatively small. Engineers of the Reliance Electric and Engineering Company have been most helpful in the procurement and preparation of the data on which the following discussion is based.

SPEED-TORQUE COMPARISON

The accepted standard of comparison for hoist drives is the performance of a constant voltage direct current system using a series-shunt or series type hoist motor. Typical performance curves for a 50 hp d-c high speed hoist with dynamic lowering control are shown in Fig. 1. The d-c series motor characteristic curves in the hoisting quadrant are ideal for hoist service These have inherent droop producing high speeds with light loads and correspondingly lower speeds at heavy loads. The operator has the "feel" of having complete control at all times. The dynamic lowering quadrant curves have a speed-load relationship opposite to that of the hoisting quadrant. Here the lowering speeds are faster for heavy loads than for lighter loads.

Performance of the adjustable-voltage system is shown in Fig. 2. The

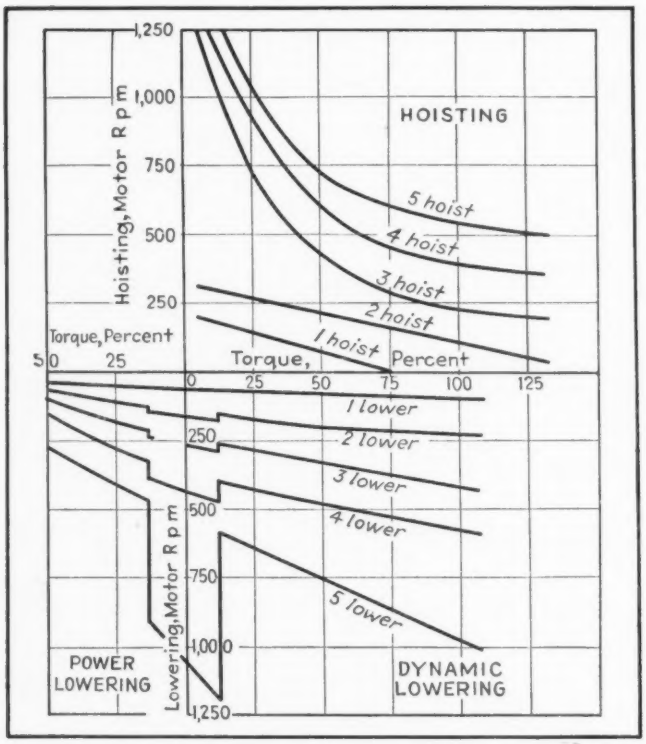


Fig. 1—Typical performance curves for a dynamic lowering high speed hoist operated on constant voltage direct current power.

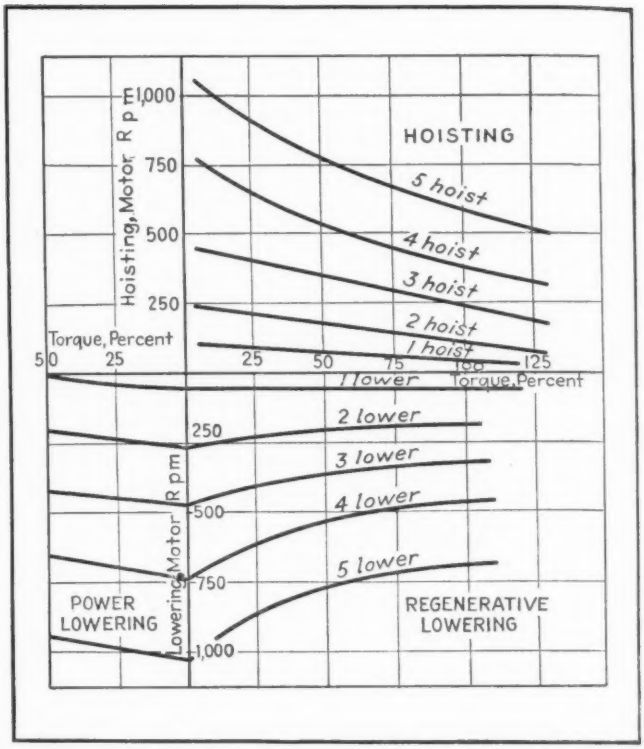


Fig. 2—Typical performance curves for a high speed hoist using a-c adjustable-voltage control. Overhauling loads regenerate power.

data, curves, and oscillograms are from tests of a full size hoist rig driven by a 50 hp d-c hoist motor under actual operating conditions, hoisting and lowering known loads of different weights. The hoist was rated at 6,600 lb and 220 ft per minute. The curves in the hoisting quadrant are similar to those in Fig. 1. But unlike the d-c system, the new system also gives similar performance curves in lowering direction. In the power lowering quadrant of Fig. 2, ample torque provides for rapid acceleration to obtain fast response under light load conditions. High light-line speeds, matching those in the hoisting quadrant are obtained. In the dynamic lowering quadrant on the same operating point of the control heavy loads are lowered at slower speeds than lighter loads, thus giving a feeling of complete control when lowering heavy loads. The operator has no hesitance in using the high speed point for lowering heavy loads so all speed points are used.

Basic Circuit

In the schematic diagram of the new circuit, shown in Fig. 3, the starting contactor *M* connects the m-g set to the a-c supply lines. For simplicity, the pushbutton and operating coil for *M* are not shown.

The adjustable-voltage armature loop circuit comprises the main generator armature, an overload relay *OL*, a load relay *LR*, a 5 volt drop resistor *R*1-*R*2 and the hoist motor armature. By means of contactors 1*FS and* 2*FS*, auxiliary fields for both the main generator and the hoist motor are connected across the *R*1-*R*2 resistor as required. Since the voltage drop across *R*1-*R*2 is proportional to the armature current, these auxiliary fields act as series fields except that they can be disconnected from the circuit.

Constant voltage direct current for the shunt fields and d-c control devices is supplied by the exciter. Direction selection is obtained by energizing the *H* or *L* relays. These reverse the main generator shunt field resulting in the proper generator polarity for hoisting or lowering.

For either hoisting or lowering, the different operating speed points are controlled by the field relays 1*FA*, 2*FA*, 3*FA* and 4*FA* commutating resistors in the shunt field circuit of the generator. These relays are interlocked to operate in succession, with no additional time delay for closing.

Relay *BR* controls the shunt coil type brake. Relay *S* connects the shunt field to the armature of the generator when the equipment is standing idle. This reduces the circulating current in the closed armature loop circuit to a low value. The normally closed *S* contacts place the generator field and armature in reversed polarity with respect to each other; thus any generator residual voltage is bucked out by its own shunt field. Such a circuit is both simple and effective.

Voltage relay *VR* connected across the main generator armature drops out at low generator voltage. Its normally closed contact limits the plugging loop circuit voltage when the master is operated rapidly from one extreme position to the other. To reduce brake wear, the *VR* normally open contact controls *BR* to delay braking until the hoist is slowed down by regenerative braking.

Operation

In the hoisting quadrant the hoist motor operates at all times as a compound motor so the contacts of 2*FS* are closed. The amount of droop of the curves in Fig. 2 primarily depends upon the amount of motor compounding, since the main generator operates as a shunt machine. On the low speed operating points, a small amount of generator compounding through contacts 1*FS* bolsters the generator voltage at low shunt field excitation. Low speeds are obtained without using resistors in the main circuit thus obtaining stable operation and relatively high efficiency.

The torque available for acceleration in the lowering direction and the speeds for driving a light hook down are shown in the power lowering quadrant of Fig. 2. In this quadrant, the hoist motor operates as a straight

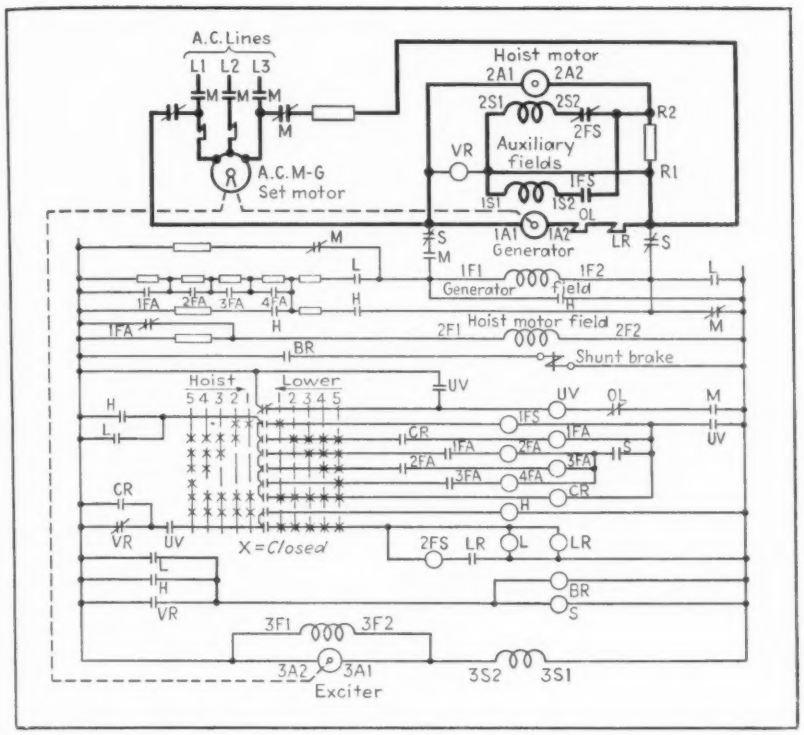


Fig. 3—Schematic control diagram for an a-c adjustable-voltage hoist system. If both brake and a-c fail while lowering, a special circuit keeps speed low.

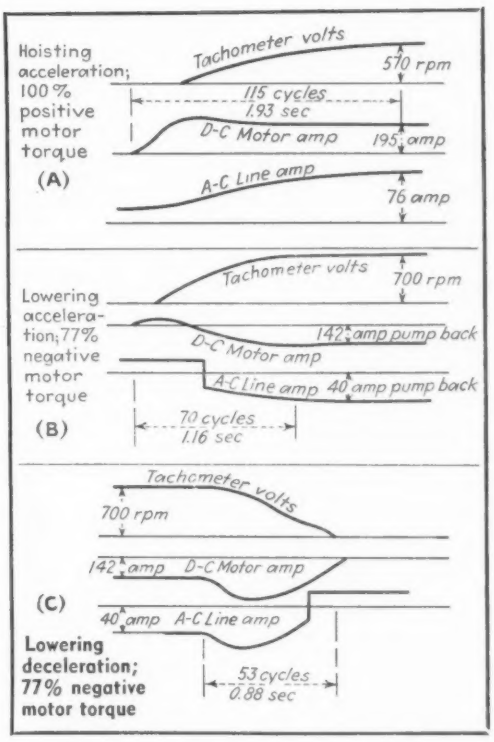


Fig. 4—Performance oscillograms for full load and speed of an a-c adjustable-voltage hoist.

shunt machine, since load relay *LR* holds contacts 2*FS* open.

With the system operating in the lowering direction, an overhauling load is lowered as shown in the regenerative lowering quadrant of Fig. 2. When the master controller is moved to the lowering side, operation is in power lowering for acceleration; but as the load overhauls the hoist the positive armature current decreases, passes through zero, and builds up as regenerative current in the opposite direction. As the armature current passes through zero, the load relay *LR* opens, contacts 2*FS* close and connect the motor auxiliary field in circuit. In the regenerative lowering quadrant the motor fields are cumulative. Because of the overhauling load, the hoist motor acts as a cumulatively compounded generator and the drooping speed-torque curves result.

The amount of regenerative power depends upon the load and the speed of lowering. Whenever the regenerative power exceeds the electrical and mechanical losses, power is returned to the a-c lines by the m-g set driving motor operating as an asynchronous generator.

Smooth Transition

Response to the master controller is quick and smooth. Because of the inherent inductive effect of the fields, smooth, stepless transition of speed is obtained and during acceleration and deceleration peaks of current in the main circuit are limited to relatively low values.

The performance results in Fig. 4 are from oscillograms taken with full rated load on the hoist. In each operation, the master controller was thrown as rapidly as possible to the maximum speed point, to obtain the peak currents and the speed of response.

In Fig. 4 (*A*), the master was moved rapidly to the fifth hoist point and the hoist motor reached full speed in less than 2 sec. Compared with a steady state load condition of 195 amp, the maximum peak of the loop current was less than 250 amp. The alternating current of the 440 volt 3 phase m-g set driving motor increased gradually to 76 amp. The hoist motor delivered full rated torque.

In Fig. 4 (*B*), the controller was moved rapidly to the fifth lower point and full speed was reached in less than 1.2 sec. Because of the reversal of the frictional effects in the mechanical system, the holdback effect required 77 percent of rated motor torque. The direct current amperes graph shows that the hoist motor took power from the generator at the start of acceleration and then began to regenerate to develop the necessary holdback. The load relay *LR* released when the d-c current passed through zero. Alternating current power was taken from the lines at the start of acceleration and then reversed with 40 amp pumped back into the power lines during steady running.

With the "steady-state", full speed, full load lowering condition of Fig. 4 (*B*), the master was moved as rapidly as possible to the off position to obtain the deceleration performance in Fig. 4 (*C*). It is interesting to note that the load and all of the moving parts were brought to a stop in less than 0.9 sec. The peak regenerative loop current was less than 150 percent rated current and the a-c regenerative peak was about 60 amp, without distress to any of the mechanical or electrical equipment.

Safety Circuits

Hoist installations usually require a safety lowering circuit, to take control in the event the solenoid-operated holding brake failed to exert sufficient torque to hold the overhauling load. The adjustable-voltage circuit of Fig. 3 incorporates a safety lowering circuit since the hoist motor operates as a series generator and exert regenerative holdback if the brake fails. The hoist motor auxiliary field produces the series generator effect and because the loop circuit resistance through the de-energized generator is low, the safety lowering speed is low.

The safety lowering circuit is stable as long as the m-g set can regenerate into the power lines, but a loss of a-c

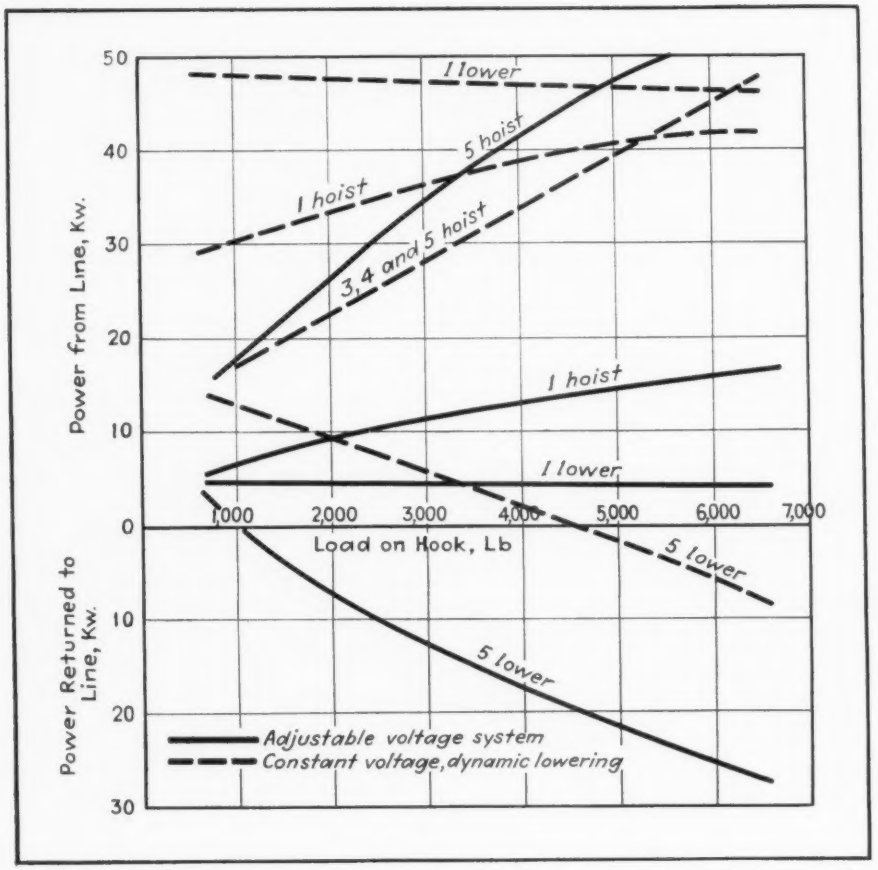
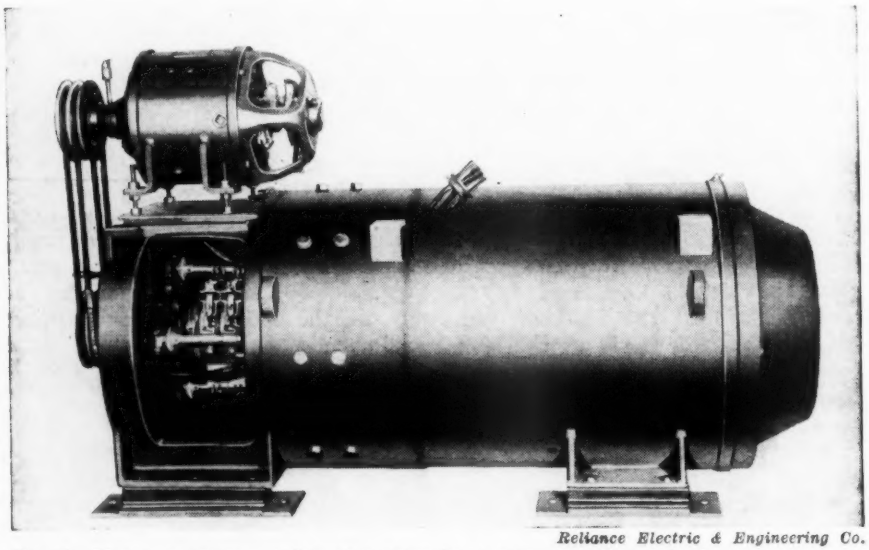


Fig. 5—Comparison of power consumption for 50 hp winch service of a-c adjustable-voltage and constant-voltage d-c dynamic lowering hoist systems. A-c system takes less.



Reliance Electric & Engineering Co.

Fig. 6—Motor, generator, and exciter comprise a compact self-contained a-c power unit.

power might let the m-g set overspeed to destruction. A novel circuit in Fig. 3 also protects against simultaneous failure of the holding brake and the a-c supply. The m-g set driving motor has 3 normally open starting contacts *M* for connection to the a-c lines and 2 normally closed contacts that connect 2 leads of the a-c motor to the d-c loop circuit. Assume the hoist control in the off position with a heavy load that causes the holding brake to slip. The load is allowed to lower slowly, with the hoist motor regenerating back through the m-g set. If the a-c power fails, the *M* contactor opens and the d-c voltage present across the loop circuit is connected to one phase of the m-g set driving motor. This d-c voltage, applied to the stator of the squirrel cage motor, produces a dynamic braking action that prevents the m-g set from over-speeding. The system settles down to a safe lowering speed where the overhauling effort of the load is absorbed by the braking in the squirrel cage motor and by the electrical losses.

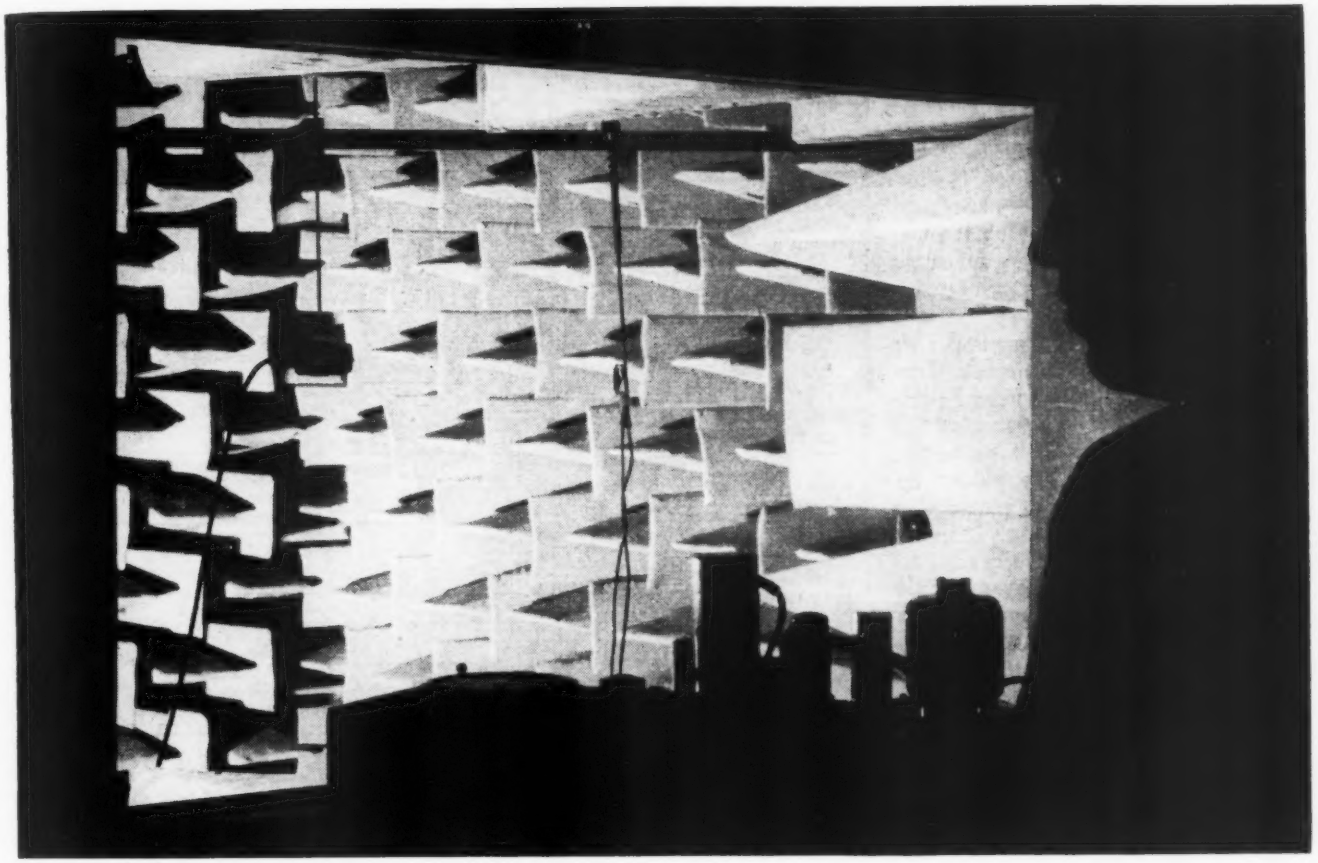
Power Consumption

The power characteristics of the adjustable-voltage system are compared in Fig. 5 with a typical constant-voltage dynamic lowering system such as used for cargo handling. The hoisting curves show how the adjustable-voltage hoist uses power in a direct relation to the loads and speeds. During hoisting, with the constant-voltage system, speed control is obtained by the use of main circuit, armature shunt and series resistors.

The power characteristics for the first and fifth points lowering are shown in Fig. 5. The second, third and fourth points are uniformly spaced between the first and fifth, but for simplicity are not shown. The constant-voltage system used a large amount of power to lower a load at slow speed because of the high current needed for series field excitation and because the resistors must provide a low armature voltage. Contrasted with this, the adjustable-voltage system consumes a small amount of power for slow speed lowering and pumps power back into the lines for higher speeds lowering. This pump back energy represents a direct saving in operating cost as it subtracts from the energy registered on the watthour meter. The curves show clearly that the adjustable-voltage system has a decided operating cost advantage on a busy hoist.

The performance and data discussed was obtained with a 50 hp conventional hoist. However, the m-g set consisted of a 25 kw generator driven by an a-c, 1,750 rpm 60 hp ½ hr duty motor with a high pull out torque. The exciter was belt driven resulting in the compact unit shown in Fig. 6. A fan on the shaft at the a-c end circulated cooling air through the unit. On a 2 hr test run of continuous cycling with rated load, the hottest part of the m-g set had a temperature rise of only 27 C.

With careful design and selection of equipment, the space and weight factors of adjustable-voltage equipments can be kept within practical limits so they merit consideration on applications where performance precision is needed. The newly developed adjustable-voltage system will be fitted into industry wherever its simplicity, flexibility, and precise performance fulfills a need better than other available systems that are now in use.



VIEW OF THE ANECHOIC ROOM at Parmlee Sound Laboratory taken through the observation window. The microphone is trained on a small relay. Precise intensity levels determined in this manner are seldom required for acoustic improvement of most products.

Fundamentals of Noise

- Relationship between sound and hearing that must be appreciated before products can be improved acoustically.
- Effect of intensity and frequency on apparent loudness and annoyance.
- The masking effect of background noise.
- Predesign considerations for good acoustic performance.

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TWO ECONOMIC FACTORS are forcing engineers to attend to the acoustic performance of their products. First, the customer is becoming increasingly noise conscious. Second, it is cheaper to design with acoustic factors in mind than to correct them in the production model.

Although reasonable success has been obtained in the acoustic design of electric fans, refrigerators, some oil heating units and some parts of automobiles, there has been almost complete dependence on cut-and-try methods. Design engineers have had little acoustic data offered to them in convenient shape for application to product development.

The problem of the engineer confronted with a noise trouble has not been that he has difficulty in finding answers, but that he is sometimes puzzled as to what questions to ask. Psychological aspects of hearing further confuse the noise analysis. What a sound meter reads and what the hearing sense perceives are often two different things. Knowledge of how the ear responds is all that one needs, sometimes, to resolve a noise problem.

This discussion of sound and its effect on the ear will be followed by later articles: basic sources of sound and sound transmission; the apparatus required for the measurement of sound; application of this knowledge to reduce acoustic annoyance in machines.

LOUDNESS

The intensity of sound is defined as the amount of energy being propagated through a square centimeter of air. The sound pressure is the alternating pressure of the air caused by the application of sound energy. The intensity I and sound pressure p are related, in a plane wave, by

$$I = \frac{p^2}{\rho c} \qquad (1)$$

where ρ is the density of the air and c the velocity of sound. The product of these last two quantities is some-

times called the specific acoustic impedance of the air and has a value of 42 g sec^{-1} cm^{-2}, or 42 acoustical units.

At 1,000 cycles the average hearing threshold is an intensity of 10^{-16} watts per square centimeter. This corresponds to an amplitude of sound pressure of 0.000 204 dynes per square centimeter. As a comparison, atmospheric pressure is approximately 1,000,000 dynes per square centimeter. The human ear can also detect sounds up to approximately 10^{-4} watts per sq cm, when pain begins to be felt. This is a range of a million times in pressure, but even the highest pressure fluctuations, those for 10^{-4} watts per sq cm, are still only 1/5,000 of an atmosphere. With this remarkable sensitivity of the ear, only minute amplitudes of vibration are needed to make sound audible. The amplitude A of a sound of a given pressure can be calculated from the equation

$$A = \frac{p}{2\pi f(\rho c)} \qquad (2$$

where f is the frequency. Thus a thousand cycle note at the level of ordinary conversation, which is 0.2 dynes per sq cm, has an amplitude of 0.76 x 10^{-6} cm, or approximately 3 ten-millionths of an inch.

To cover the million-to-one range of pressure to which the ear is sensitive, it is convenient to use decibel units, the decibel being defined by

$$\text{db} = 10 \log \frac{I_2}{I_1} = 20 \log \frac{p_2}{p_1} \qquad (3)$$

where I_2/I_1 is the ratio of two intensities, and p_2/p_1 the ratio of two sound pressures. If a pressure of 10^{-16} watts per sq cm is taken as the threshold of hearing, one can speak of a sound being so many "decibels above the threshold," which is usually shortened to so many "decibels." A scale in Fig. 1 shows the decibel levels of sounds that the average listener might hear.

The important psychological fact is that the response of the ear is not linear with pressure. There are marked variations of apparent loudness with intensity and frequency. Therefore, it is necessary to refer to a set of loudness contours, Fig. 2, the well-known Fletcher-Munson curves (see Fletcher and Munson, *Journal of the Acoustical Society of America,* Vol 6, p 82, 1933). It will be noticed that only above 90 decibels are the curves fairly flat. This means meter readings of intensity have to be converted in order to measure loudness. Typical machine sounds have been added below the chart to indicate their relative frequency. Since these machine sounds may vary a great deal in their intensity, the ordinary speech levels are given as a reference intensity.

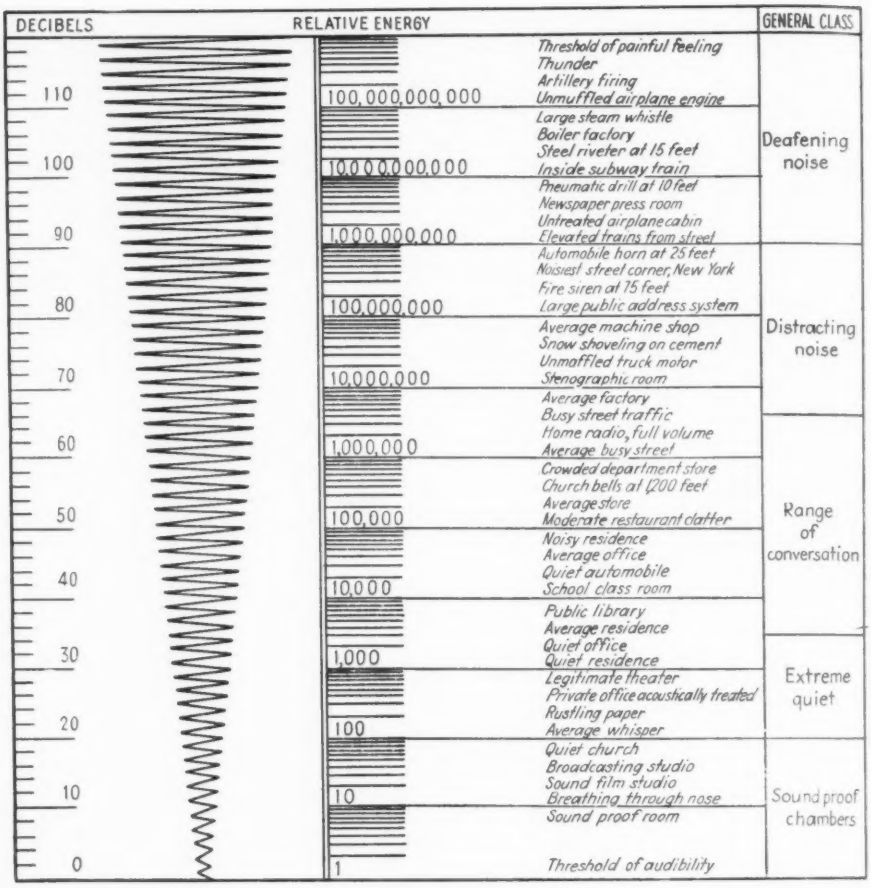


Fig. 1—Decibel and equivalent energy for common sounds, comparing the intensities of everyday noises. *Courtesy of The Journal of the Western Society of Engineers.*

Curves that convert sound intensity measurements to loudness units are given in Fig. 3. Curve A is for 100 cps, where the sound intensity must be 38 decibels above the 1,000 cps threshold in order to be heard at all. Curve B is for 300 cps and Curve C for the 800-2,000 cps region. The curves for the higher frequencies are parallel to C, with greater loudness for the same intensity at 3,000 cps and reduced loudness at the higher frequencies. The human ear can hear up to a frequency between 10,000 and 24,000 cps, depending on the individual.

Curves A, B and C are only for pure tones. When a sound consists of more than one tone, it will sound louder than a pure tone, even though the intensity is the same. For instance, a 300 cps fundamental and nine equally intense harmonics, 600,

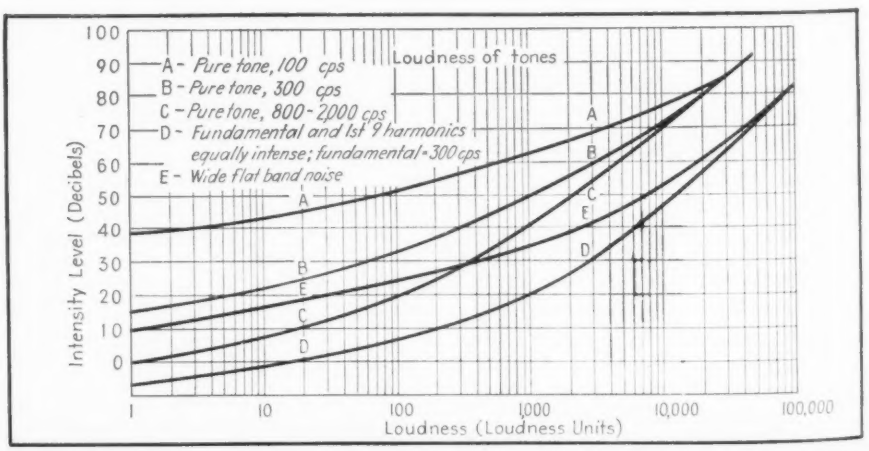


Fig. 3—Curves for translating pure and mixed tones of various frequencies into loudness.

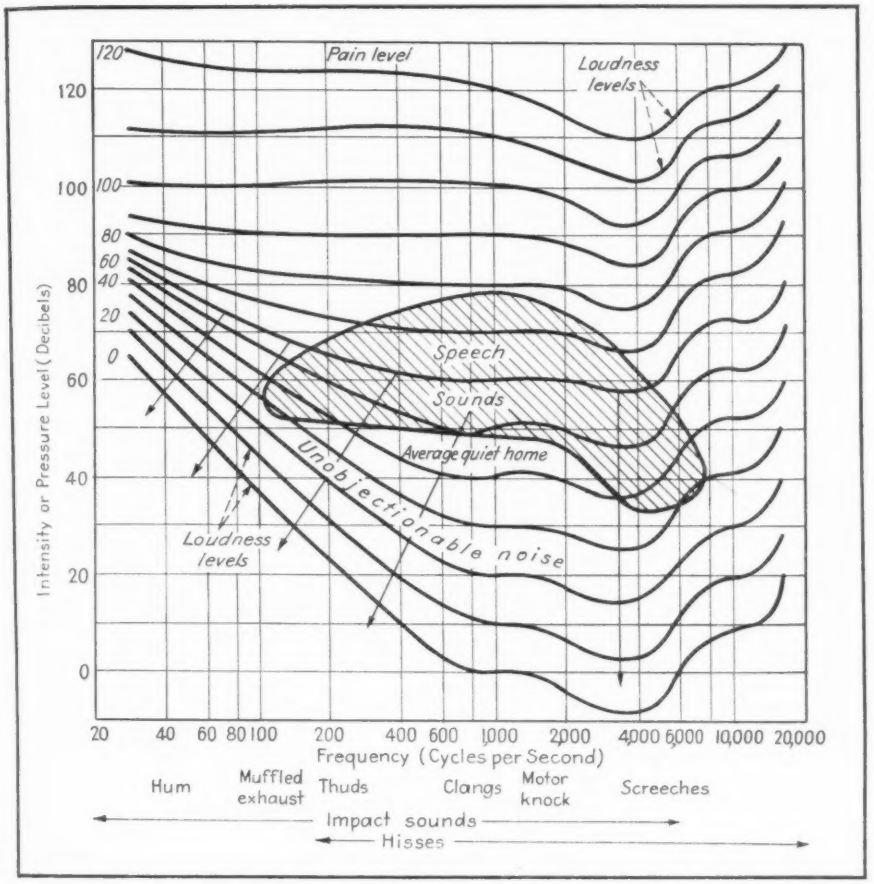


Fig. 2—Fletcher-Munson contours of equal loudness show how the ear interprets noises for different intensities and frequencies. Arrows indicate direction of design objective.

900, 1,200, etc, give the loudness Curve D. (For further information on the subject consult *Bell Telephone Technical Monograph* B-1937. "Pitch, Loudness, and Quality of Musical Tones" by Harvey Fletcher.) A broad band noise source with all frequencies present gives Curve E (see Fletcher and Munson, *Journal of the Acoustical Society of America,* Vol 9, pp 1-10, July, 1937). One can see, therefore, that sound meter readings, which are essentially pressure measurements, are misleading if a simple correspondence between intensity and loudness is assumed. This does not mean that good acoustic measurements cannot be made. It does mean that the interpretation is as important as the measurement.

Annoyance

The annoyance of a sound is not directly proportional to the loudness. Not too accurate measurements have been made of annoyance, although it is well known that high frequencies are more annoying than low. The results of some measurements at Harvard University are given in Fig. 4. (See "The Relative Annoyance Produced by Various Bands of Noise", Harvard Psycho-Acoustic Laboratory. PB-27306. Office of the Publication Board, Department of Commerce.) As frequency is increased from 100 to 10,000 cps there is about ten decibels increase of annoyance.

Other factors that contribute to the annoyance are: intensity flutter, frequency flutter or warble, and certain combinations of tones. Also, sounds at large random intervals are usually much more disturbing than sustained noises. Little quantitative work has been done on these effects.

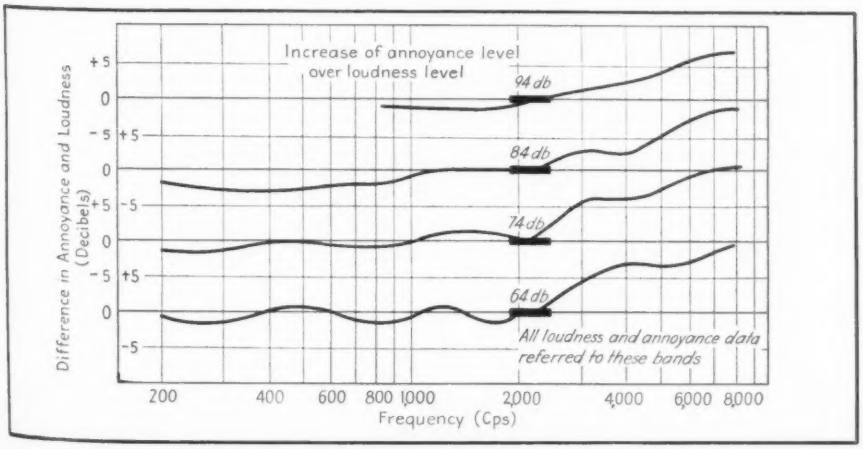


Fig. 4—As frequency increases, annoyance rises faster than loudness.

Background Noise

Background noise is an important factor which is generally overlooked. Such noise tends to mask the presence of other sound sources. A clock ticking or a clicking thermostat relay can be most disturbing in the quiet of the night, yet go unnoticed in ordinary daytime activity.

Background noise is most effective in masking a sound when there are frequency components in the background close to the frequency of the sound being emitted. In a wide band noise background it is possible to hear a pure tone when its intensity level is approximately 20 decibels below the noise level. This is because of the selective nature of the ear.

Most of the noise in the environment of the average person consists predominantly of components of low frequencies. This makes the high frequencies much more noticeable. Coupled with the facts that the ear is less sensitive at lower levels in the low frequency region, Figs. 2 and 3, and that the higher frequencies are much more annoying, Fig. 4, it can be seen why good design reduces high frequency sound. A reasonable job of sound control often consists of simply lowering the frequencies of the sound source without appreciably changing the intensity level. This again points out the importance of the true interpretation of sound level measurements.

The product engineer must learn in what acoustic environment his product will be used and what the average noise will be in that environment. The Bell Telephone Laboratories have measured the noise level in the average residence. Ninety percent of the homes are in the range between 33 and 52 decibels with an average of 43 decibels (see D. F. Secord, "Room Noise at Subscribers' Telephone Locations," *Journal of the Acoustical So-*

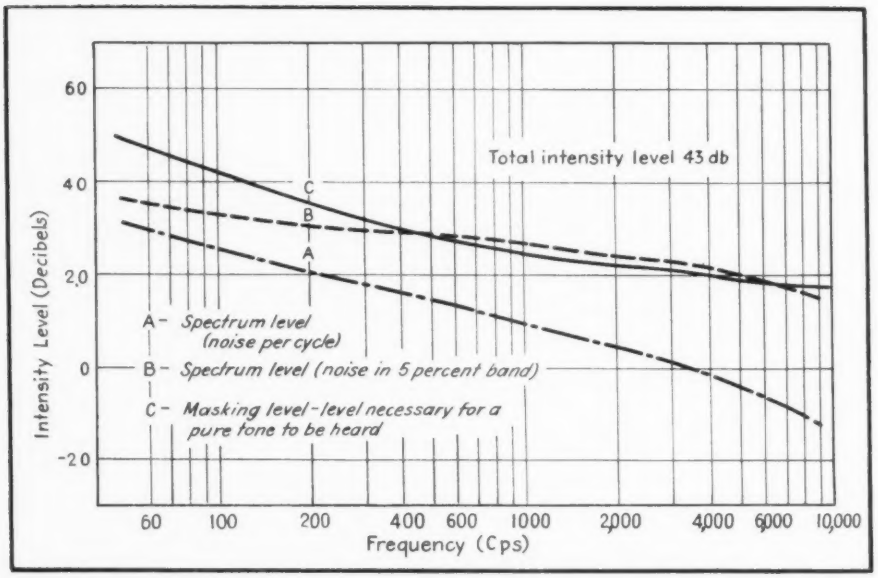


Fig. 5—Curve A is the spectrum level in the average home. Pure tones in household equipment should be held below Curve C, so they will be masked by the background noise.

ciety of America, Vol 12, pp 183-187, July, 1940). The spectrum, or frequency distribution, of this noise at 43 db is given in Fig. 5 (see D. F. Hoth, "Room Noise Spectra at Subscribers' Telephone Locations," *Journal of the Acoustical Society of America,* Vol 12, pp 449-504, April, 1941; and Harvey Fletcher, "Hearing, the Determining Factor for High Fidelity Transmission, *Proc. IRE,* Vol 30, pp 266-277, June, 1942). Curve A is the noise per cycle; Curve B the noise in a band that has a width of 5 percent of the frequency at the center of the band. This is about the band width of the General Radio sound analyzer. The masking level of this noise is given by Curve C; that is, a pure tone would have to be as high as the masking level shown to be heard. This curve may be taken as the design goal of the noise spectrum for products to be used in the home.

Preliminary Acoustic Considerations

The following is a suggested series of acoustic questions that the engineer should answer in the early design stages.

1. In what background noise level will the product be used?
2. What is the spectrum of the background?
3. What noise level does previous experience lead one to expect from the particular product?
4. What noise spectrum will the product have?
5. How much quieting will be sufficient and in what part of the spectrum will this be necessary?
6. Is there likely to be a particularly annoying effect from the repetition rate or other factors in the noise?

These questions having been answered, the designer is ready to tackle the problem of where the noise comes from. This will be taken up in the second article of this series.

Cost-Reducing Powder Metallurgy Techniques

Outstanding wartime developments in German powder metallurgy appear in report prepared by Dr. Gregory Comstock, director of powder metallurgy laboratory of Stevens Institute of Technology, as a result of information gathered on two trips as an OTS investigator.

In developing powder metallurgy techniques, the Germans worked along different lines from American metallurgists. This was especially true in the manufacture of sintered carbide hard metals. The Germans relied entirely on the "hot press" method, while American industry pressed cold and sintered in a separate step.

Outstanding war development in the hard cemented carbide industry appears to have been the standardization of compositions and methods of manufacture. Also of importance are numerous new steps pertaining to fabrication processes. The hot press, used in production or cores for armor-piercing projectiles and in development of tungsten-free cutting materials is reported to be most interesting.

Americans have long recognized the advantage of using a hot press to quickly and inexpensively produce very large objects of hard cemented carbide or a limited number of pieces of intricate cross-section, but have been faced by difficulties.

German technicians surmounted the difficulties usually associated with simultaneous application of great heat and pressure—loss of molten binder by extrusion—by using carefully weighed prepressed charges with a constant apparent density to control final volume.

The German hot press is of the graphite resistance type, a spring-clamped mold being the resistor. A separate mechanical or hydraulic system is used for applying top and bottom plunger pressure. Technicians designed a series of auxiliary machines for mass producing mold, plunger and separator forms.

All types of molten metals, alloys or even emulsions of nonalloying metals were disintegrated by a rotating disk method. The process, developed by Deutsche Pulvermetallurgische Gesellschaft and licensed for use by eight other metal plants, is relatively simple. Molten metal, superheated in the case of metals of high melting point, flows through a funnel crucible having a nozzle 7 to 9 mm in diameter, and strikes a disk. The disk has knives mounted on it and rotates at high speed. The molten stream is inclosed by a water cone formed by a ring nozzle fixed below crucible outlet.

Size and shape of particles is changed by varying rotation speed of the disk from 2,000 to 6,000 rpm, and by regulating the water nozzle. The powder, washed into a container by water used in the cone, forms a slime that is then dried. The resulting powder has a particle size of about 0.6 millimeters. Copper, silver and aluminum powders have been produced by this process.

Metal powders were also produced by pressure atomization with steam. The shape of iron powder particles produced by this method is more nearly spherical than those produced in the rotating disk method, but "pressability" is not as satisfactory.

Orders for the report (PB 39354r "German Powder Metallurgy", 128 pages mimeographed, $3.25) should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., accompanied by check payable to the Treasurer of the United States.

ENGINEERING ABSTRACTS

FOREIGN AND DOMESTIC ARTICLES

Some New Developments in Steel

From a paper "New Developments in Steel" by Dr. M. A. Grossman, director of Research, Carnegie-Illinois Steel Corp., presented before local chapter of American Society for Metals, Des Moines, Iowa.

STEEL PROPERTIES. In the past few years it has become more and more apparent that true mechanical behavior can only be explained ultimately in terms of fundamental properties. Therefore, increased attention has been given to flow and fracture conditions and especially to behavior under multiaxial stresses.

Numerous failures in welded merchants ships early in the war emphasized the need for a better understanding of the behavior of steel under severe service conditions involving notches, severe constraints, low temperatures, sudden loadings, etc. Experiments on models of hatch corners and on large 6 x 10 ft tensile specimens (believed by some to simulate service conditions) indicate that with few exceptions steels can be rated as to their behavior in these tests by the order of their transition from tough to brittle behavior in the notched bar impact test.

With such correlations, it seems more essential than ever that the mechanics of the impact test be understood, and that the mechanism of resistance to crack propagation be studied in terms of fundamental flow and fracture properties.

Another field of relatively intense activity is sheet metal forming. New approaches to the problem have been made through the fundamental material properties. The mechanics of forming operations must be clearly understood so that the requirements placed on the metal can be ascertained and the material properties of importance determined, especially for flow under multiaxial stress.

Information has been obtained on the effect of various alloying elements in steel on corrosion resistance. As a consequence more intelligent use of high strength and low alloy steels is now possible in various corrosive environments. Development of new synthetics provide better corrosion resistance coatings. Of particular interest is the war development of new inhibitive paints with zinc chromate.

NEW PRODUCTS. Stainless W, an age hardening 18-8 steel, is one of the few really new developments in stainless steels in recent years. Attempts in this direction necessitated cold working to produce aging In this new development, aging is obtained without cold working. Depth of hardening is not limited by hardenability considerations and the uniform hardness of Rockwell C-45 has been obtained through a 6 in. cross-section of materials. There appears to be no limitation to the depth of hardening. Previously, the desirable combination of hardness, high strength and corrosion resistance of 18-8 was limited to products obtained only by cold working, such as sheets, strip, wire, and tubes. Extensive research revealed that the composition of Stainless W must adhere quite closely to the following percentages: 0.07 C, 0.50 Mn, 0.010 P, 0.010 S, 0.50 Si, 7.00 Ni, 17.00 Cr, 0.70 Ti, 0.20 Al, balance Fe.

The intergranular corrosion of 18-8 is a precipitation of carbide. Since it had not been possible to make 18-8 steel free of carbon, the harmful carbon behavior had been circumvented by adding titanium or columbium to the steel. This precipitates the carbon in the form of harmless titanium carbide or columbium carbide. But titanium and columbium are expensive and sometimes entail certain difficulties. Thus by a neat trick in physical chemistry, it is possible to make 18-8 so low in carbon that intergranular corrosion is vastly reduced and sometimes eliminated.

Again in the field of 18-8 stainless, the war found renewed attempts to avoid the use of nickel. Numerous publications referred to the use of nitrogen, which strangely enough is very powerful in stabilizing austenite, although the amount that can be used is limited.

Extending beyond the 18-8 into the range of higher alloy contents, there has been increasing demand for alloys having strength at high temperatures, during the war for such applications as superchargers, and now for such fields as gas turbines. The amount of alloy was gradually increased, until indeed in many instances there was no longer much iron. Outstanding at these upper limits were the nickel-base alloys, the cobalt-base alloys, and Parke's vacuum-melted chromium-base alloys.

In addition to N. E. Steels, another factor in conserving alloys during the war was boron, which played possibly a minor role and yet in its way a spectacular one. Fantastically small amounts of 0.002 to 0.003 percent of boron substantially increased hardenability. Greater amounts were less effective and even harmful, so the use of boron had its limitations. A dozen various proprietary ferro-alloys now incorporate boron.

OTHER STEELS. Many agencies and some steel producers are trying to improve the quality of ordinary ship plate for hull construction by enhancing the notch toughness of plain carbon steels without reducing the strength level. Work on the regular ship plate material used extensively during the war indicated that the start of the transition of a typical semi-killed material in ½ in. thickness is about +35 F and for 1 in. plate is about +60 F. By simply lowering the carbon and raising the manganese in a semi-killed grade, the start of the transition for a typical material would be —25 F and 0 F respectively. It has been further demonstrated that if this lower carbon, higher manganese type is made silicon-aluminum killed, the start of the transition might be represented by —60 F for ½ in. plate and —25 F for 1 in. plate. But the significance in service of materials showing these differences in transition temperatures in the notched bar test has not been established, although the trend is in the right direction.

The outstanding development in sheet and strip products within the past five years is the widespread ap-

plication of aluminum killed steel for deep drawn objects. This grade of steel has superior forming qualities and for that reason has supplanted the selected rimmed grade of steel formerly used for automobile fenders and similar articles.

Ti-Namel, developed by Inland Steel Company and Titanium Alloy Manufacturing Company, is said to take a cover coat vitreous enamel without a prior blue (cobalt) ground coat. Reportedly it derives superior enameling properties because titanium combines with carbon to form a stable carbide.

During recent years many manufacturers of high strength steels for structural applications have made improvements in their proprietary grades. Most of the changes made have been in the direction of adding nickel, reducing phosphorus, and investigating deoxidation practices for the purpose of improving weldability, rollability, and low-temperature toughness. During this time, some new and improved grades of high strength steel have been introduced including:

Aldecor: A silicon-copper-molybdenum steel with phosphorus.

Improved Hi-Steel: A copper-nickel steel with phosphorus, changed by lowering the carbon and phosphorus and adding molybdenum and aluminum.

Improved Cor-Ten: A silicon-copper-chromium steel with phosphorus, improved by decreasing the phosphorus, silicon, and chromium and adding a small amount of nickel. This resulted in better performance in the T-bend weld test and in the notch-bend impact test.

Manganese-Nickel-Copper: A grade with good average properties for a high strength steel.

The use of electrolytic tin plate during the war period was a necessity due to tin shortage. One-half pound of tin per base box supplemented by a lacquer coat was substituted for many uses where hot dipped plate with heavier weights of coating (1.25 to 1.50 pounds) were used before the war. The installation of electrolytic tinning units and development of complex mechanism for their operation involved the expenditure of many millions of dollars. Naturally, these modern lines are high speed in operation. They required continuous research in mechanical and electrical control devices, conveying equipment, and chemical engineering. Research studies of variables of operating practice such as black plate preparation, surface finish, annealing, temper pass, pickling, plating, electro-melting, chemical treatment, oiling and finishing operations have resulted in a clearer understanding of the effect of these operations on the quality and suitable uses for this product. Corrosion studies have resulted in a clearer knowledge of the mechanism of can failure. Standard practices have been established to insure uniform quality of this type of tin plate, which may not replace the hot dip variety but will probably increase in volume.

CONTROL. Marked progress has been made in the development of instruments and control devices for continuous hot rolling, cold reduction, shearing, coating, finishing and inspection equipment for flat rolled steel products. Electronic devices of new design control some of these high-speed continuous operations. With cold reduction speeds as high as 3,500 fpm, a close control of mill pressure and tensions are required to obtain uniform thickness. Coil annealing equipment has been increased in size and uniformity of control. Rolling speeds in temper rolling have attained approximately 2,500 fpm. Electrolytic tinning speeds have increased from 200 to 500 to 1,000 fpm. With such operations manual control is impractical.

WELDING. During the war, most of the tremendous expansion of welding was because of increased use of existing processes. One exception was the inert gas shielded metal-arc welding, that uses a non-filler-metal tungsten or carbon electrode shielded by an envelope of helium or argon. These gases exclude the nitrogen and oxygen of the air. Such welding is useful particularly in the field of nonferrous metals.

One new electrode development is the controlled hydrogen electrode that is covered with a coating that evolves little or no hydrogen. In this respect the coating is similar to that on a stainless steel electrode. Such electrodes inhibit the formation of cracks in the base metal underneath the weld metal.

HEAT TREATMENT OF STEEL. In relation to obtaining strength by quenching and tempering, there is increasing realization of the importance of microstructures. This involves the inter-relation of the structures pearlite, bainite, and martensite. The importance of hardenability is recognized in establishing limits in the form of hardenability bands (so called H-bands), which in heat-treating problems are coming to be recognized as being more important than a rigid adherence to narrow chemical specifications.

Induction hardening is increasing in the industry. Decisions to use it are often based as much on compactness and convenience of using the equipment as on performance of the heat-treated product.

Refrigeration of hardened steel, or deep-freeze treatment, is receiving increased attention. As is known from much earlier investigations, the effect is to transform austinite that was retained in the microstructure in the quench into martensite. Possibly one factor in the increased popularity of the treatment is the greater availability of refrigerating equipment. The treatment seems to be useful in some applications, especially some tool steels, but for other applications the merit seems questionable.

TESTING. Sound waves are used for searching out imperfections in steel, at frequencies in the supersonic range. (P. E. Oct. 1947, pg. 113) In the supersonic test a quartz crystal contacting the piece to be tested through an oil film sends into the work a few sound waves of short wave length. This wave group is reflected from the side of the work most distant from the crystal and upon returning and striking the crystal generates in it a voltage whose time of arrival is indicated on a cathode-ray oscilloscope. Any imperfection is detected by its reflecting a part of the wave group, and this reflection arrives at the crystal before the reflection from the distant side of the work. Thus the length of path travelled by the reflected wave can be calculated.

Glass-To-Metal Sealing

From "New Techniques in Glass-to-Metal Sealing" by Joseph A. Pask, Westinghouse Electric Corporation, presented March 4, 1947, at the annual meeting of the Institute of Radio Engineers.

THE USUAL TECHNIC of making glass-to-metal seals consists of cleaning the metal, properly oxidizing it to develop a strong vacuum-tight seal, and sealing the glass to the metal while it is still hot. Consequently, in seals made on the glass lathe, success is dependent entirely upon the skill and judgment of the operator, which is especially true on large and intricate

seals. He must decide whether he is oxidizing sufficiently and whether a firmly adhering oxide layer has been obtained.

The development of a "powder glassing" method at the Research Department of the Westinghouse Lamp Division enables the making of seals on a scientifically controlled basis.

Data are presented for Kovar oxidized at various lengths of time and controlled temperatures. Excellent adherence of glass to Kovar is obtained with a weighted gain of 0.0003 to 0.007 g per sq cm, regardless of temperature of oxidation.

The powder glassing method of making seals consists of grinding the glass, suspending the powdered glass in a suitable liquid, applying it to the prepared metal, and fusing to form a thin glass layer. The glass tube or bulb is subsequently joined to this layer as a glass-to-glass seal.

Applications of this technique include part of the liquid air trap of a mass spectrometer, which has a Kovar seal close to a heavy copper tube. Prior to use of the new method, common sealing techniques resulted in a shrinkage of about 40 percent. The powdered glass method produces successful seals, with no shrinkage.

This technique also allows the making of multi-section blanks employing butt seals. Such butt seals could not be made on a glass lathe. An advantage is that powder glassed parts can be stored indefinitely.

Air Traffic Control Systems for Safer Flying

From a paper "Air Traffic Control," by C. W. Carmody, Chief Air Route Control Section, Civil Aeronautics Administration, presented before AIEE, September 1947, Dayton, Ohio

NEW FACILITIES that have been or are being developed for air navigation, communications, and traffic control include:

INSTRUMENT LANDING SYSTEM. ILS is being installed as a standard airport facility. Present program contemplates about 100 completed installations by the end of June 1948.

ILS comprises three elements: The localizer, glide-path, and marker beacons. Approach lighting and radar surveillance are additional components of a complete Instrument Landing System.

Aircraft equipment for using the ILS system utilizes a cross-pointer instrument for indicating signals from the localizer and glide-path. Movement of top-pivoted vertical needle to right or left indicates lateral deviation from the localizer and movement of the left-pivoted horizontal needle indicates deviation above or below the glide-path. A series of three small lights light up in turn as the aircraft passes over the marker beacons. The output of the localizer and glide-path receivers can be connected to a form of automatic pilot for extremely accurate approach.

VHF RADIO RANGE. The Omni-Directional VHF radio range is far superior to the previous two-course visual range. The Omni-Directional range (VOR) provides a course at any compass bearing from the station. This facility utilizes the same aircraft receiver and adds to the instrument panel a Course Selector, by which the pilot selects the course desired, which is then flown using the cross-pointer instrument, and an Ambiguity Indicator, which indicates whether the course flown is toward the station or away from it.

The Omni-Directional radio range has been adopted as the standard airway facility to replace the present low frequency ranges, and an extensive installation program is well under way. The complete program includes over 400 stations, which probably will be installed by June 30, 1948.

DISTANCE MEASURING EQUIPMENT (DME): As an adjunct to the ILS and VOR, a substitute for marker beacons and other methods of position fixing has been developed. The DME is a facility to be installed at localizer and VOR stations which will permit a pilot carrying the necessary receiver to read his distance from the navigation facility on a dial. The aircraft DME receiver will be so integrated with the navigation receiver that tuning to the proper localizer or range frequency will automatically tune the associated DME facility.

Another development is the Offset Course Computer. When also installed in the aircraft, it permits selection of not only radials of the VOR but also any other course, not passing over the station, within the coverage of the radio range. This equipment would permit establishment of airways containing several parallel lanes of air traffic at the same level.

AUTOMATIC COMMUNICATION AND POSTING

VHF AIR-GROUND COMMUNICATIONS. A great stride has been made in improvement of communications between aircraft and the ground through adoption of VHF channels that eliminate static and increase readability within a limited range. This includes a separate group of channels for each class of aircraft to use in talking to ground stations and towers, as well as a group of channels for towers to transmit to aircraft in flight. Separate channels are set aside for communication between the tower and aircraft or vehicles on the ground. In addition, there are simultaneous voice channels on the radio ranges and the ILS localizer. These are received simultaneously with the navigation signals and permit navigation and communication with only one receiver.

Development work is being done on radio-teletype and radio-facsimile.

To replace present communication nets and manual posting of data two things are necessary: (1) A simple and automatic communication system; and (2) a method of display of flight data in the centers, preferably actuated directly by the communications system. Principal disadvantages of the systems developed to date include cost of such systems compared to possible personnel savings, limitations in the displays that ordinarily use numerals and numerical codes, and the inflexibility of such a system with the impending changes in the air navigation and air traffic control system due to adoption of the new facilities.

RADAR. In adapting radar to civil aviation, problems include: (1) Increasing the rotation rate of the antenna; (2) increasing the vertical span of the airspace scanned; (3) increasing the reliability of the equipment and decreasing maintenance required; and (4) developing operational use of radar. The greatest problem in the use of radar has been the lack of a "daylight scope" that does not require complete darkness for readability.

Two major uses for radar are being

field-tested for traffic control. First is the monitoring of traffic flow in airport and approach control operation. Several types of "Surveillance Radar" have been tried. Search radar scanning of the terminal area can aid greatly in insuring proper separation during final approach, speed up departure procedures, assist in detecting unreported aircraft, and provide for emergency assistance to lost aircraft. Requirements include: (1) Range of 30 to 40 miles; (2) a vertical coverage from the ground to 45 deg above the horizontal; and (3) a sweep speed of 30 rpm. The 12 in. scope shows distance and azimuth of all aircraft within a 10, 20, or 30 mile radius. An essential adjunct is an MTI (Moving Target Indicator) circuit that eliminates all returns from fixed objects causing "ground clutter."

In addition to Surveillance Radar, Precision Radar is being tested. Precision Radar consists of two radar units that scan a limited segment of airspace in the approach to the instrument runway. One unit scans the approach path vertically, measuring the elevation and distance of aircraft from the approach end of the runway and the other scans the same sector horizontally, measuring deviation right or left of the center-line of the runway as well as distance. The data are displayed on another 12 in. scope divided into two parts; elevation and distance are on the upper half, and lateral deviation and distance on the lower half.

OTHER DEVICES AND SYSTEMS. Many other devices and air traffic control-air navigation systems are being developed, including TELERAN, LAMAC, block-signal systems, airborne radar, anti-collision devices, and radar navigation equipment, which have not been described in detail herein. Some of these devices are in the field trial or operation test stages of development, but their eventual use and/or the type equipment to be adopted is still undecided.

Welding High-Temperature Alloys

From "Welding Characteristics of Various High-Temperature Alloys" by C. G. Chisolm, Haynes Stellite Company, presented October 21, 1947, at the annual meeting of the American Welding Society.

USE of the new high-temperature alloys has been confined, almost exclusively, to the aircraft industry, since these alloys were developed for the buckets and blades of aircraft supercharger and turbo-jet engines. Because of wartime secrecy, restrictions of information prevented many concerned with high-temperature problems from experimenting with the alloys under their own operating conditions. Full development of these alloys as practical materials of construction for all high-temperature applications has been retarded because little information has been published on their welding characteristics.

As far as welding characteristics are concerned, these alloys can be divided into three general groups. These are:

Group I—Cobalt and cobalt-nickel-base alloys.

Group II—Nickel-base-alloys.

Group III—Cobalt-nickel-iron base alloys.

At room temperature, the ultimate tensile strengths and yield strengths decrease from Group I to Group III, and elongation values increase. Thus, Group I are more difficult to work and form than the alloys in Group II or Group III. This is also true of the welding characteristics, but not to the same degree.

These alloys can be welded by all methods used with the austenitic stainless steels. They can be welded to each other or to dissimilar alloys. The coefficients of expansion are about 50 percent greater than those of mild steel, and the heat conductivity is only about one-fourth that of low-carbon steel. The electrical resistance, particularly in the work-hardened condition, is higher than that of carbon steel. Because of these properties, care must be taken to prevent distortion and residual welding stresses.

When sheet and plate are welded, properly designed jigs and fixtures are important. The sequence of welding should be planned to avoid stresses that result in cracking. Accurate fitting and edge preparation are essential to assure sound welds, and to avoid cracks resulting from notch sensitivity. Formed and work-hardened parts should be annealed.

The alloys in Group II and Group III can be joined by roller-seam welding. Long welds have been made successfully by this process. A stainless steel exhaust stack on a jet engine has been fabricated by roller-seam welding. Similar sheet-metal parts have been made from "Hastelloy" alloy C and "Multimet" alloy sheet. Welds produced by this method are sound, clean, and strong.

Metallic-arc welding is a satisfactory method for joining high-temperature alloys because it is fast and accurate. In general, joint designs established for stainless steel are acceptable for joining high-temperature alloys. Coated electrodes are available for joining all of these materials. Sheet-metal parts in a collector ring have been joined by the metallic-arc process. This same method is also used to join precision castings to sheet-metal parts.

Joining blades to wheels for high-speed gas turbines and rotors was one of the most difficult problems encountered in welding high-temperature alloys.

One hundred alloy No. 30 (Table I) blades, 2 in. long, were joined to a "16-25-6" alloy wheel, ½ in. thick and 15 in. in dia by manual and metallic-arc welding. A standard A.W.S. "U" joint, with a tang width of 0.090 in. and a groove width of ½ in. was used. Half of the "U" form was carried on the wheel and half in the blade.

Combinations of alloy Nos. 21, 30, and 31 blades have been welded to "16-25-6" alloy, (Timken Roller Bearing Company) and "Multimet"

Table I—Analysis of Cobalt and Cobalt-Nickel-Base Alloys

	Alloy No. 21	Alloy No. 23	Alloy No. 27	Alloy No. 30	Alloy No. 31
Carbon	0.20 to 0.35%	0.35 to 0.50%	0.35 to 0.50%	0.35 to 0.50%	0.45 to 0.60%
Chromium	25 to 30%	23 to 29%	23 to 29%	23 to 29%	23 to 28%
Nickel	1.50 to 3.50%	1.50% max.	Balance	12 to 17%	9 to 12%
Tungsten	.....	4 to 7%	.....	.....	6 to 9%
Molybdenum	4.50 to 6.50%	.....	5 to 7%	5 to 7%	.....
Iron	2.0% max.	2.0% max.	2.0% max.	2.0% max.	2.0% max.
Cobalt	Balance	Balance	30.0 min.	Balance	Balance

Table II—Analysis of High Temperature Alloys

	"Hastelloy" alloy B	"Hastelloy" alloy C	"Multimet" alloy (low carbon)	"Multimet" alloy (medium carbon)
Carbon	0.12% max.	0.15% max.	0.20% max.	0.30 to 0.40%
Chromium	.....	12 to 16%	18 to 22.5%	18 to 22.5%
Nickel	Balance	Balance	18 to 22%	18 to 22%
Molybdenum	26 to 30%	15 to 19%	2.75 to 3.75%	2.75 to 3.75%
Columbium	.....	.....	0.75 to 1.50%	0.75 to 1.50%
Tungsten	.....	3.5 to 5.5%	2 to 3%	2 to 3%
Iron	4 to 7%	4 to 7%	Balance	Balance
Cobalt	.....	.....	18 to 22%	18 to 22%
Nitrogen	.....	.....	0.10 to 0.20%	0.10 to 0.20%

alloy wheels using these same electrodes. No. 316, "Inconel 132," and "Hastelloy" alloys B and C (Table II) have been used with some success in experimental wheel welding.

The "Unionmelt" welding process, which consists of welding electrically beneath a granulated material, is also used with high temperature alloys. Because this process is a fast method of joining blades to wheels, fabricators are experimenting with this process for other applications, involving the welding of high-temperature alloys. One manufacturer recently used alloy B and C wire with this process, and is experimenting with a modified alloy B wire with a 5 percent chromium addition.

The atomic-hydrogen process has been used for production welding these alloys, and is particularly applicable for welding sheet-metal parts. In this process, the solidifying weld metal is protected from oxidizing by a blanket of hydrogen gas. No flux is required when welding with the atomic-hydrogen process, and bare welding rods may be used as a filler.

In the "Heliarc" welding process an inert monotomic gas, such as argon or helium, is used to prevent oxidation in the weld metal. Generally a single electrode of tungsten is used, but carbon electrodes may be substituted if proper care is taken to prevent carbon absorption in the weld metal material.

Heat Resistant Glass for High Light Intensity

Foreign abstract, condensed from "A Heat-Resisting Glass," in *The Engineer* (London), March 21, 1947, page 249.

WHERE high light intensities are needed for industrial applications, the heat associated with the production of light causes many difficulties. It is therefore necessary to remove this heat from the stream of radiation without reducing the amount of light transmitted.

One difficulty is that the body being lighted gets heated from both visible and invisible radiation. Requirements of the glass which transmits the radiation are that it absorbs the invisible part of the spectrum without changing the color of the light; and it must have heat resisting properties, such as low thermal expansion.

A glass which is claimed to combine the required properties, and produced on an unusual type of base, has been developed. It is virtually colorless, it does not absorb or change the color of any light falling on it, and it absorbs almost completely all the invisible infra-red portions of the spectrum which cause heating. This glass is known as "Chance ON19," and is available in flat sheets of various thicknesses.

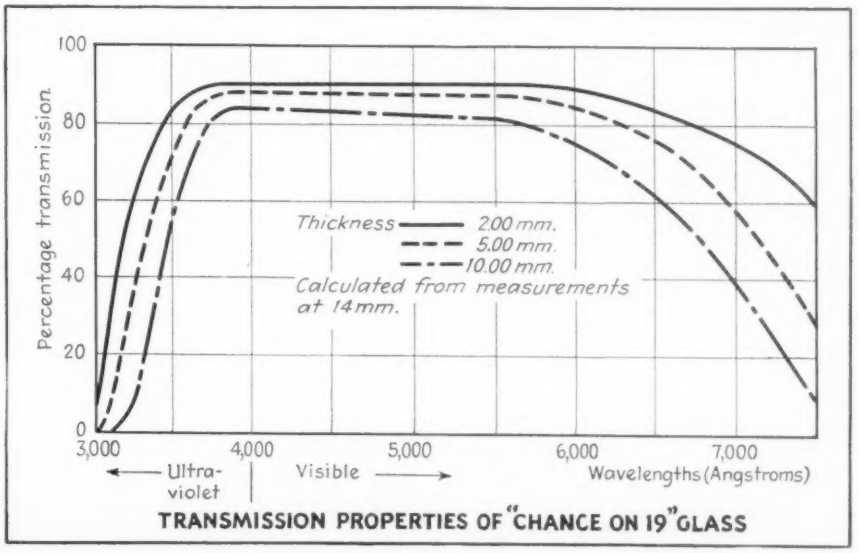
Physical properties of the glass are indicated in the accompanying table.

Since ON19 glass has the property of almost complete absorption of the infra-red rays, it gets very hot in use, and in spite of its low expansion, serious strains can be set up, particularly when the radiation does not fall uniformly on the glass. In a projection system, a heat absorbing filter must be placed somewhere between the lamp and the film. The best place is somewhere near the condenser lens and preferably on the lamp side of the condensers in order that the condensers themselves shall be subjected only to cool light. A small gap should be left between the glass and the condenser. It is frequently an advantage to cut the glass into strips so as to minimize stresses because of uneven heating, but in such cases, care must be taken that the edges are smooth, and the glass must not be mounted so tightly that it is fractured.

Thickness Relation for Light-Heat Transmission (2848 deg. K)

Thickness mm.	Light percent	Heat percent
0.5	91.3	39.0
1.0	90.3	23.0
1.5	89.0	19.0
2.0	88.0	14.0
3.0	87.0	8.5
4.0	85.0	6.5
5.0	83.0	5.5
6.0	81.0	4.5

Refractive index	1.505
V-value	66.5
Specific gravity	2.5
Thermal expansion	59×10^{-7}
Annealing temperature	550 C



TRANSMISSION PROPERTIES OF "CHANCE ON 19" GLASS

Pivoted Centrifugal Friction Clutches

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Professional Mechanical Engineer

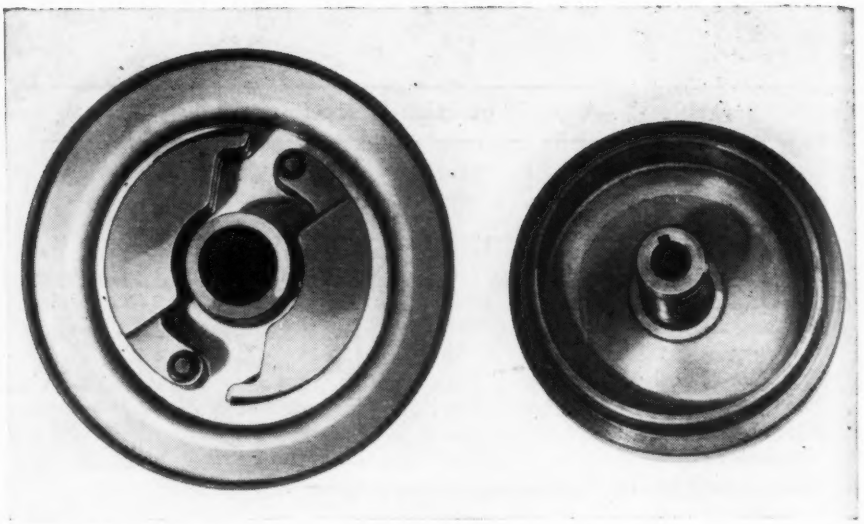


Fig. 1—A typical pivoted centrifugal friction clutch design. Shoes are mounted on a V-belt pulley flange. Drum is mounted on driven member.

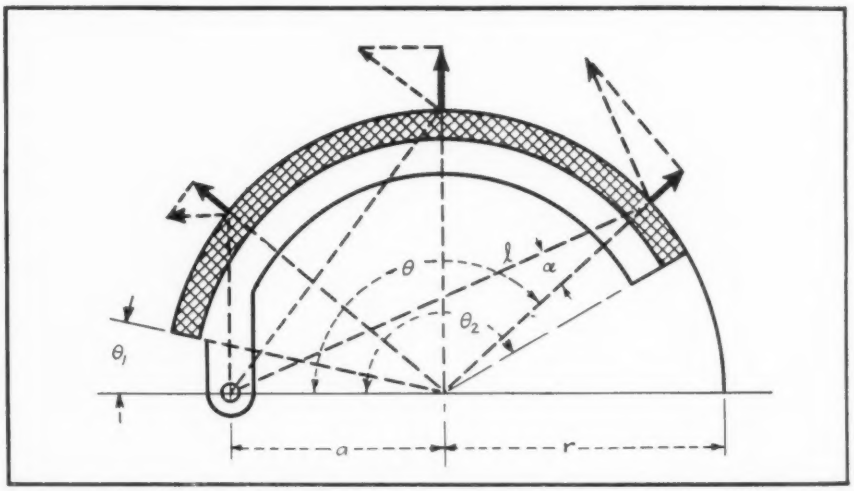


Fig. 2—A diagram showing the radial components of the lining velocity vectors as the shove moves around the pivot during the wearing process.

BY SELECTING lining lengths and locations so that the linings are loaded to their maximum working capacity, designs for friction clutches are both compact and economical. In the pivoted centrifugal friction clutch this is accomplished by making a mathematical analysis of the pressure variations along the surface of the shoes.

When designing a drum type friction clutch, values for required torque, allowable lining pressure, drum size, speed of operation and friction coefficient are known. The location and length of lining and the physical dimensions of the shoes can be determined by mathematical analysis. The approximate life of the clutch can also be calculated.

If neither drum nor lining wore, pressure would be distributed uniformly over the entire lining. The operating conditions between drum and lining can be described by assuming an inflexible lined shoe to be forced in place over the pivot so that pressure against the drum occurs only in the section near the pivot. Infinitesimal clearance is given on the remainder of the lining surface. If a single force is applied to the shoe and the drum is rotated, the lining begins to wear. As the lining material wears away, the pressure near the pivot will diminish and the lining will assume a loading along the surface farther away from the pivot. Simultaneously the shoe will turn about the pivot in the direction of the drum to equalize the forces. As wear continues, a point is reached where the lining pressure is approximately uniform. The pressure would then be constant if further wear could be stopped. Since linings do wear, pressure around the circumference of the shoe will vary.

The rubbing velocities for all points on the working surface of the lining can be assumed to be identical if infinitesimal circumferential movements resulting from wear are disregarded. Since new lining surface has to be supplied as fast as it wears away, points of maximum pressure will correspond to those of maximum wear. Thus, the pressure at any point is a function of the rate at which the lining is used up at that point.

PRESSURE DISTRIBUTION ON THE LINING. Referring to Fig. 2, the pressure is proportional to wear or to the radial component of the lining velocity vector drawn from the shoe pivot to any point on the lining. This vector of course has an infinitesimal value compared with the rubbing velocity.

Let

r = radius of shoe, in.
a = distance from shoe center to pivot, in.
θ = displacement angle from pivot line, deg
l = distance from pivot to a point on lining, in.
α = angle between pivot line and radius to point, deg
p = pressure at any point on lining, psi
v = radial velocity vector component in. per sec
K = constant of proportionality

From the preceding analysis, p is proportional to v. From Fig. 2, v is proportional to $l \sin \alpha$.

Since

$$l \sin \alpha = a \sin \theta$$
$$p = K a \sin \theta$$

Since a/r is constant,

$$p = K_o r \sin \theta$$

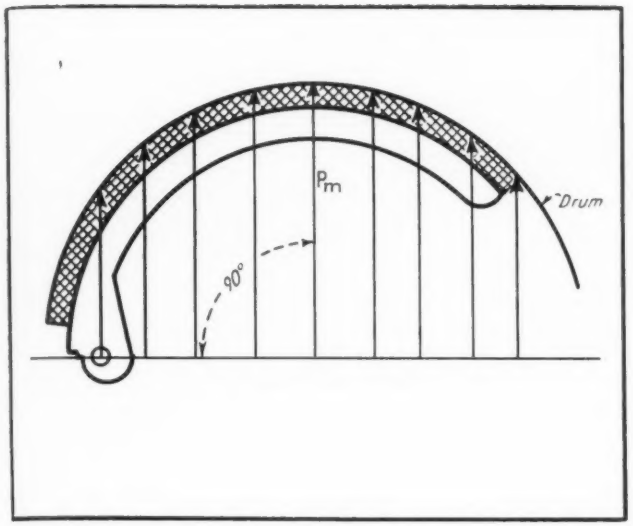


Fig. 3—The relative pressure on the lining is the ordinate from the diametral line that passes through the pivot center point.

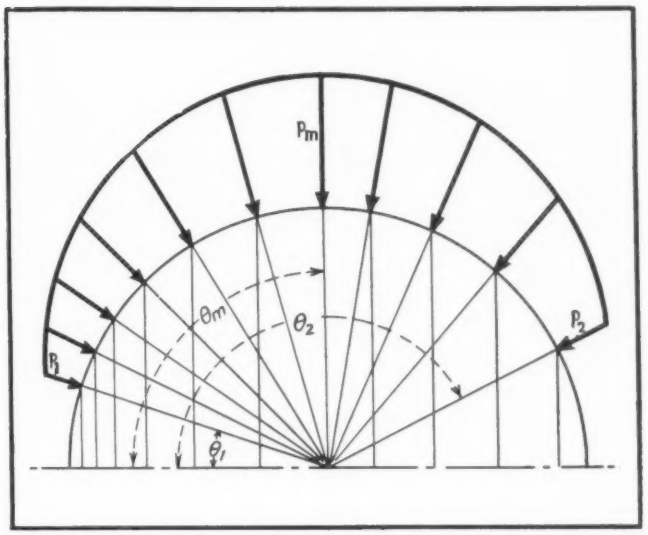


Fig. 4—A pressure diagram for a full half lining. The maximum pressure occurs at the point where θ equals 90 degrees.

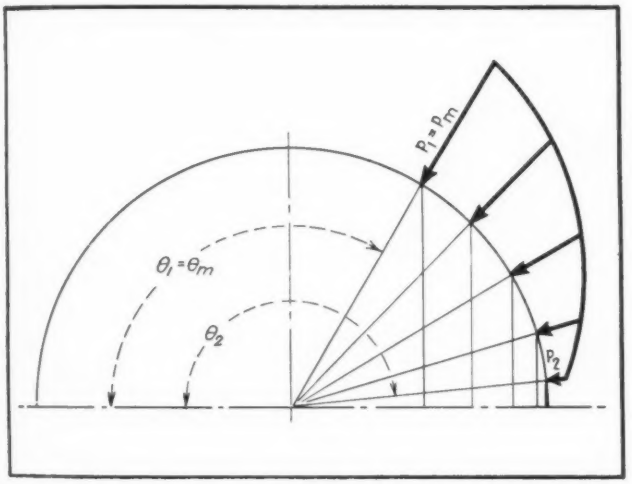


Fig. 5—A pressure diagram for a partial lining. The maximum pressure occurs at the point nearest θ equal to 90 degrees.

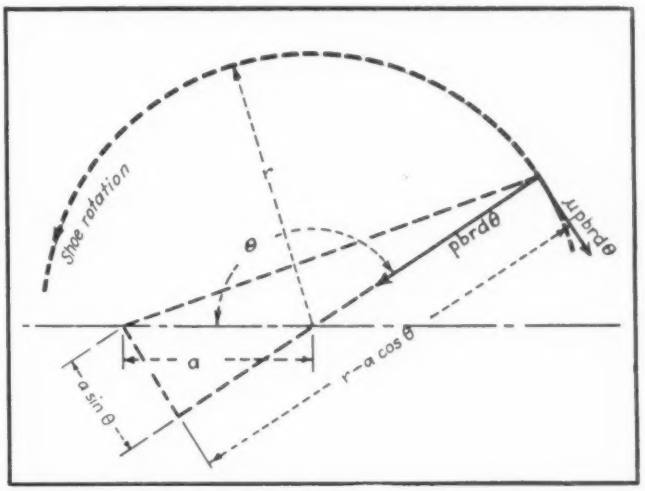


Fig. 6—Forces acting on the lining to produce the pressure moment and the energizing moment as the lining engages the drum.

Therefore the relative pressure, as shown in Fig. 3, is the ordinate from the diametrical line that passes through the pivot. If p_1 and p_2 are pressures at any two points

$$p_1 = K_1 \sin \theta_1$$
$$p_2 = K_2 \sin \theta_2$$

If the material is assumed to be consistent, then

$$K_1 = K_2,$$

and

$$p_1 = p_2 \frac{\sin \theta_1}{\sin \theta_2}.$$

If p_2 is taken as p_m, the maximum working pressure on a continuous arc of lining, then

$$p = \frac{p_m}{\sin \theta_m} \sin \theta \qquad (1)$$

In Eq (1), p is the pressure at any point and θ_m is the angle to the point of maximum pressure.

Referring to Figs. 4 and 5, it can be seen that if the lining is continuous, with θ_1 less than 90 deg and θ_2 equal to or greater than 90 deg; then θ_m is 90 deg and p equals $p_m \sin \theta$. If θ_2 is less than 90 deg, θ_m equals θ_2 and the pressure p_2 at θ_2 is

$$p_2 = \frac{p_m \sin \theta_2}{\sin \theta_2} = p_m$$

When θ_1 is greater than 90 deg, then θ_m equals θ_1, and the maximum pressure occurs at the end nearer θ equals 90 deg. If the lining is discontinuous, the same pressure relations hold, but the determination of pressure and friction moments about the shoe pivot requires separate integration.

AVERAGE PRESSURE. Over any continuous arc of the lining circumference the average pressure p_{av} is:

$$p_{av} = \frac{p_m}{\sin \theta_m} \times \frac{1}{(\theta_2 - \theta_1)} \int_1^2 \sin \theta \, d\theta$$

$$p_{av} = \frac{p_m}{\sin \theta_m} \frac{(\cos \theta_1 - \cos \theta_2)}{\theta_2 - \theta_1} \qquad (2)$$

PRESSURE MOMENT. From Fig. 6, let

M_p = pressure moment about pivot, in.-lb.
b = lining width, in.

$$dM_p = \frac{p_m}{\sin \theta_m} \times \sin \theta \, (brd\theta) \, (a \sin \theta)$$

$$M_p = \frac{p_m (abr)}{\sin \theta_m} \int_{\theta_1}^{\theta_2} \sin^2 \theta \, d\theta$$

$$M_p = \frac{p_m (abr)}{4 \sin \theta_m} [2(\theta_2 - \theta_1) - \sin 2\theta_2 + \sin 2\theta_1] \qquad (3)$$

DRUM TORQUE. Let

M_d = drum torque per shoe, in.-lb.
μ = lining coefficient of friction

$$dM_d = \frac{p_m \sin \theta}{\sin \theta_m} \times brd\theta \mu r$$

$$M_d = \frac{p_m (b\mu r^2)}{\sin \theta_m} \int_{\theta_1}^{\theta_2} \sin \theta d\theta$$

$$M_d = \frac{p_m}{\sin \theta_m} (b\mu r^2) (\cos \theta_1 - \cos \theta_2) \qquad (4)$$

If lining extends over entire surface

of a semi-circular shoe, then θ_1 equals 0 deg, θ_2 equals 180 deg and θ_m equals 90 deg then

$$M_d = 2\, p_m\, b\, \mu\, r^2 \qquad (4a)$$

ENERGIZING MOMENT. Let M_e equal energizing moment about pivot, in-lb.

$$dM_e = \frac{p_m}{\sin \theta_m} \sin \theta\, (b\mu r)\ (r - a \cos \theta)\, d\theta$$

$$M_e = \frac{p_m\, (b\mu r)}{\sin \theta_m} \left[r\, (\cos \theta_1 - \cos \theta_2) + \frac{a}{2} (\sin^2 \theta_1 - \sin^2 \theta_2) \right] \qquad (5)$$

NET RESISTING MOMENT. If M_n is the net resisting moment then

$$M_n = M_p \pm M_e \qquad (6)$$

The plus sign is used if the relative motion of drum and shoe tends to release the shoe. This means that the applied moment about the shoe pivot must be increased by the value of M_e over the pressure moment M_p to obtain drum torque M_d.

CENTRIFUGAL MOMENT. The centrifugal moment is equal to and opposes the resisting moment. In Fig. 7, r_1 and r_2 are the principal radii of a pivoted mass of width b in. and density of δ lb per in.^{3} The mass is rotating at an angular velocity of ω rad. per sec. The mass of the lining is not included in this analysis but may be considered when necessary. The letter g is the acceleration of gravity. If dF is the amount of centrifugal force on any element of mass at radius r then, neglecting pivot friction, the centrifugal moment about the pivot, $d\ M_c$, equals $a \sin \beta\ dF$ and

$$M_c = \frac{ab\ \delta\omega^2}{12\ g} \int_{r_1}^{r_2} \int_{\beta_1}^{\beta_2} r^2 \sin \beta\ dr\ d\beta$$

$$M_c = \frac{ab\ \delta\omega^2}{36\ g}\ (r_2^3 - r_1^3)\ (\cos \beta_1 - \cos \beta_2) \qquad (7)$$

PROCEDURE IN APPLYING FORMULAS. Eq (4) can be used as a starting point. Values for required torque per shoe; lining width, friction coefficient and radius may be used to determine the location of the lining. A simple method is to assume the lining location and solve for the radius or width of lining, since θ_m can be determined by inspection as the point of maximum lining pressure, see Figs. 3 and 5. The value for p_m is another required value. The required centrifugal moment M_c can be expressed in terms of known values by writing M_d in terms of M_p and M_e

From Eq (6)

$$M_e = M_p \pm M_c$$

$$M_e = M_d \frac{a}{r} \left\{ \frac{[2\ (\theta_2 - \theta_1) - \sin 2\theta_2 + \sin 2\theta_1]}{4\ \mu\ (\cos \theta_1 - \cos \theta_2)} \pm \frac{(\sin^2 \theta_1 - \sin^2 \theta_2)}{2\ (\cos \theta_1 - \cos \theta_2)} \pm \frac{r}{a} \right\} \qquad (8)$$

The plus signs are used when rotation diminishes the moment and the minus sign with opposite rotation. The value of M_c from Eq (8) is substituted in Eq (7) to determine the unknown quantity. In this solution the many factors used may require some selected values as a start. The result given by each formula applies to one shoe. The number of shoes must therefore be considered in the first step.

For an electric motor driven clutch, the torque input must be kept as high as possible without exceeding the pull-out torque. Here the shoe should run so that the friction moment tends to reduce the centrifugal moment on it. The location and extent of the lining depend somewhat upon the service expected of the clutch. As the material thickness is limited to rather small size, a relatively long length of lining is necessary where duty is heavy. Consequently much of the material will be operating below its capacity. This is unavoidable and results in termination of running life before complete wear on all of the lining has taken place. Where duty is light the lining may be short and placed where most effective.

The lining may be placed near to the pivot to gain mechanical advantage, but it should be remembered that p_m is to be the same for all locations and that wear is most consistent in the vicinity of θ equals 90 deg as shown later. Eq (4) should be checked; assume θ_1 and determine θ_2 in degrees.

Note from Eq (4) that when everything else is constant, available torque varies as the square of the drum radius.

The distance a is usually made as large as is practicably possible, so that a/r is approximately 0.75 to 0.90. The effect of a variation in a/r has negligible significance unless carried to an extreme lower limit. Thus, for the absurd case where a equals 0, Eq (8) becomes indeterminate, while Eq (3) correctly causes M_p to vanish. However, Eq (5) gives a finite value for the energizing moment and this may be viewed as being caused by a tight lining, which is wedged into place. This would give a value for M_d since in such a case p_m would be finite. The clutch would become a spring loaded device with the centrifugal feature vanishing entirely.

EXAMPLE. The following values are given for designing a centrifugal friction clutch.

No. Shoes = 2
μ = 0.35
r = 1.734 in.
b = 15/16 in.
δ = 0.41 lb per in.^{3}
M_d = 15 in-lb per shoe
β_1 = 20 deg
β_2 = θ_2
ω = 116.2 rad. per sec
p_m = 40 psi
θ_m = θ_1 = 133 deg
a = 1.406 in.

With reference to the equations developed previously, one should first

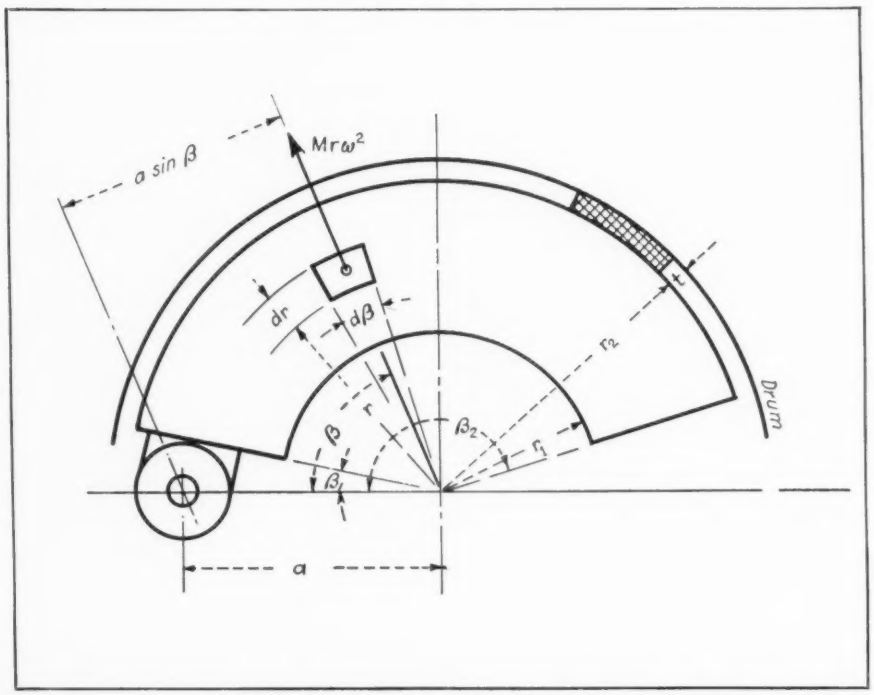


Fig. 7—Forces acting on the mass of the shoe required to determine the centrifugal moment.

Fig. 8—Close-up view of a worn lining showing crescent shaped wear pattern.

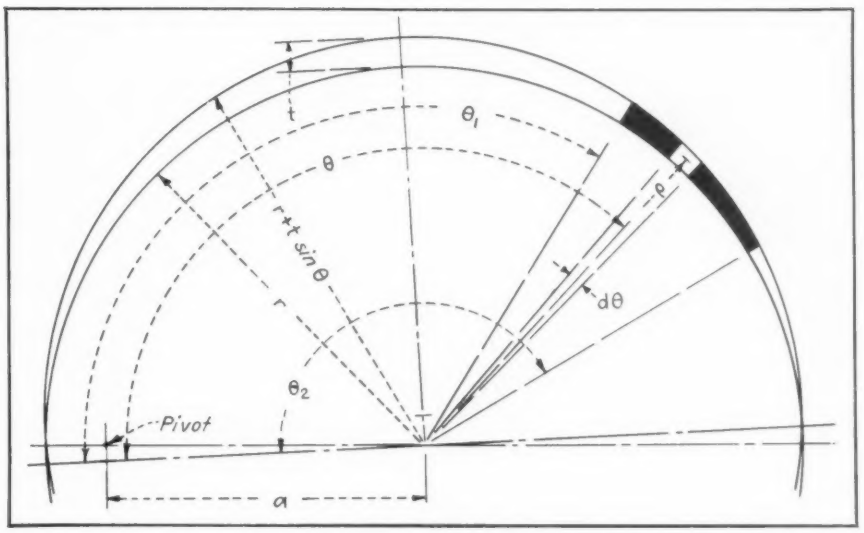


Fig. 9—A diagram that is used to develop equations for the approximate life of the clutch lining. A crescent shaped wear pattern is assumed.

first solve for θ_2 by substituting values in Eq (4).

$$\cos\theta_2 = \cos\theta_1 - \frac{M_d \sin\theta_m}{p_m\, b\, \mu\, r^2}$$

$$\cos\theta_2 = 0.6820 - \frac{15 \times 0.7314}{40 \times .9375 \times 0.35 \times 3.00}$$

$$\cos\theta_2 = -0.9602$$

$$\theta_2 = 163,8 \text{ deg}$$

Next substitute in Eq (8) and solve for M_c, using the plus sign to indicate non-energization.

$$M_c = \frac{a}{r} M_d \left\{ \frac{[2(\theta_2 - \theta_1) - \sin 2\theta_2 + \sin^2 2\theta_1]}{4\,\mu\,(\cos\theta_1 - \cos\theta_2)} + \frac{(\sin^2\theta_1 - \sin^2\theta_2)}{2(\cos\theta_1 - \cos\theta_2)} + \frac{r}{a} \right\}$$

$$M_c = 0.8105 \times 15 \times \left\{ \frac{[2 \times 0.537 + 0.5358 - 0.9976]}{4 \times 0.35 \times 0.2783} + \frac{0.5355 - 0.0779}{2 \times 0.2783} + 1.234 \right\}$$

$$M_c = 44.1 \text{ in-lb}$$

From Equation (7)

$$r_1^3 = r_2^3 - \frac{36g\, M_c}{ab\, \delta\omega^2} (\cos B_1 - \cos B_2)$$

$$r_1 = \sqrt[3]{4.16 - \left(\frac{36 \times 32.2}{1.406 \times 0.9375} \times \frac{44.1}{0.41 \times 13,510 \times 1.9} \right)}$$

$$r_1 = 0.775 \text{ in.}$$

This clutch in actual performance delivered a torque of 29 in-lb using r_1 β_2 25/32 in. and a cast iron drum.

LIFE OF LINING. The horsepower hours service is approximately proportional to the material available for wear. Therefore the running lifetime of a lining can be predicted when a value for horsepower hours service per cubic inch of material has been determined. In Figs. 8 and 9, the material available for wear is the crescent shaped section or portion thereof with a thickness of lining t at θ equals 90 deg. At that point of the shoe all of the original thickness is considered to be expended. If the lining does not include this point and the centrifugal mass includes the point, the limiting value t is still used because clutch life terminates when any portion of the metal of the shoe contacts the drum. If β_2 is less than 90 deg, there will be more material available for wear than the formulas indicate, because the lining can wear to zero thickness at the end nearer θ equals 90 degrees.

The amount of material available for wear can be computed for any angular incremeent in terms of t. Rivet holes in the lining are disregarded. The two circular arcs bounding the area have the same radius r in. neglecting drum wear. The relation between them is simplified as follows:

$$\rho = r$$

$$\rho = r + t\sin\theta$$

These simplifications avoid complicated final expressions. This results in an inexact expression for the area. However, the error is vanishingly small. These relations indicate that the circles intersect at 0 deg and 180 deg, which is obviously incorrect. These limits may be used since the intersections are flat and will cancel the small error when final simplification is made. Referring again to Fig. 6, the area A, the square inches of lining available for wear, can be expressed as follows:

$$A = \int_{\theta_1}^{\theta_2} \int_{r}^{r + t\sin\theta} \rho\, d\,\theta\, d\,\rho$$

$$A = \tfrac{1}{2} \int_{\theta_1}^{\theta_2} d\,\theta\, (2rt\sin\theta + t^2\sin^2\theta)$$

$$A = \left[-rt\cos\theta + \frac{t^2}{2}\left(\frac{\theta}{2} - \frac{\sin^2\theta}{4}\right) \right]_{\theta_1}^{\theta_2} \quad (9)$$

If θ_2 equals $\pi/2$ and θ_1 equals zero, the value of A for a quarter-lining is:

$$A = rt + \frac{\pi}{8} t^2$$

or

$$A = rt\left[1 + \frac{\pi}{8} - \left(\frac{t}{r}\right)\right] \quad (10)$$

Neglecting the second term in the bracket, Eq (10) reduces to

$$A = rt$$

For a complete half lining

$$A = 2rt = Dt, \text{ where } D = 2r$$

For any length of lining Eq (9) can be simplified to:

$$A = rt\,(\cos\theta_1 - \cos\theta_2) \quad (11)$$

When t/r is $\frac{1}{16}$, the error resulting from using Eq (11) is less than $2\frac{1}{2}$ percent. A 60 deg lining, which extends from θ_2 of 120 deg to θ_1 of 60 deg gives an area rt. This value is the same as a lining extending from 0 deg to 90 degrees.

When using Eq (11) to determine the life of the clutch lining surfaces, the following procedure is used. First a value of the transmitted horsepower hours service per cubic inch of lining material is determined by tests. Next the volume of lining material available for wear is found by multiplying the value of A from Eq (11) by the width and number of shoes. Multiplying the first value by the second gives the approximate life of the clutch. The specific value for horsepower hours service per cubic inch of material can also be used as a starting point in designing a centrifugal clutch for a specified life of operation.

Gear Trains for Multiple Speeds

Design procedure in calculating single step ratios in gear trains for obtaining a range of final speeds. Progression ratios, gear train subdivisions and aggregate number of teeth are discussed. Graphical methods are described for making a preliminary analysis of the proper relations, proportions and sequence of the single step ratios.

LOUIS DODGE

IN MACHINERY, gear trains having sliding gears are widely used to obtain a range of final speeds from a constant speed input shaft. Yet many designers have given slight attention to the fundamental principles upon which calculations for efficient gear trains are based. The designer usually approaches such calculations in a haphazard way. Different combinations of pitch and gear diameter are considered and calculated. Then these are changed to suit practical center distances and gear sizes. Finally, he adopts one combination that seems to meet the specified requirements. Quite often the designer cannot be sure that the scheme he adopts is the best one to use for his design.

The designer's objective should be a mechanically sound and economical gear train. One that combines a geometric progression series of final speed variations with the highest possible mechanical efficiency and the smallest space requirements. The attainment of such an objective is facilitated by paying proper attention to several design considerations:

1. To prevent interference when shifting gears, the difference between pitch diameters of adjacent gears on the same shaft, or in a sliding cluster, should be the amount required for at least four teeth.

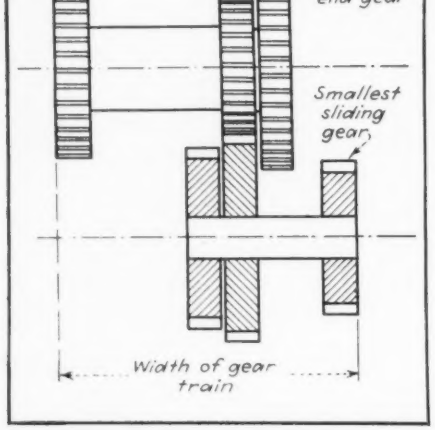


Fig. 1—Gear train in which smallest sliding gear moves past a fixed end gear.

When a gear train having very small ratios is to be designed, the requirement of a pitch diameter difference of 4 teeth results in a high aggregate number of teeth. This unfavorable condition can be improved by arranging the gears so that the smallest sliding gear moves past a fixed end gear, Fig. 1. By this method the pitch diameter difference equivalent to 4 teeth can be reduced to 2 and the aggregate number of teeth be kept to a minimum. The overall width of the gear train, of course, will be increased by an amount equal to twice the width of one gear.

2. The axial length of a gear train is shortest when the gear cluster is made the sliding member.

3. For satisfactory construction and operation, a cluster of sliding gears should consist of not more than three gears.

4. To avoid undercut and to be assured of unimpaired engagement of mating gears, do not choose less than 20 teeth for the smallest gear in the train.

5. Use, if possible, the same diametral pitch throughout the gear train, and compensate for differences in tooth loads by increasing the width of the gears where necessary.

6. The aggregate number of teeth (of the same pitch), or the sum of the pitch diameters, of all mating gears on the driven and the driving shafts must be the same.

7. The aggregate number of teeth of two mating gears having a ratio of a/b should be divisible by

$$a + b$$

8. The most favorable aggregate numbers of teeth are those that have 2 and 3 for common factors.

9. To avoid synchronous vibrations, deviate slightly from even ratios.

10. Check permissible pitch line velocity of spur gears. Do not exceed a pitch line velocity of 2,000 ft per min for commercially cut metallic gears. For further data see "Dynamic Loads on Gear Teeth" and "Manual of Gear Design" by Earle Buckingham.

The prerequisite to the achievement of a proper speed variation is the application of a suitable progression series to the contemplated gear train.

In a geometric progression series, successive terms are obtained by multiplying the preceding term by a constant k, called the progression ratio. Expressing the first term as unity, the sequence in a geometric progression series of n terms is

$$1, k, k^2, k^3, k^4 \ldots\ldots\ldots k^{n-1}$$

In this series, all terms but the first are multiples of k. It is obvious that the ratio of the nth term to the first term is

$$(k^{n-1})/1 = k^{n-1}$$

This series has a unique quality in that the product of any two terms is equal to another term in the same series.

In gear train design, the adoption of a standard progression ratio as the basis for selecting a speed ratio series for mating gears has many advantages. Such a procedure facilitates the solution of problems dealing with the speed changes, simplification of design, transmission of energy, utilization of material and cost of manufacture.

Of the many progression ratios put forward, the Androuin progression ratio,

$$\sqrt[10]{10} = 1.259 \cong 1.26$$

possesses many advantages as the basis for gear train calculations. The Androuin ratio is a single step or single ratio in the decimal series known as the Decimal Geometric Progression (D.G.P.).

For practical design purposes, the single-step ratios given in Table I will be found useful.

The German Industrial Standard

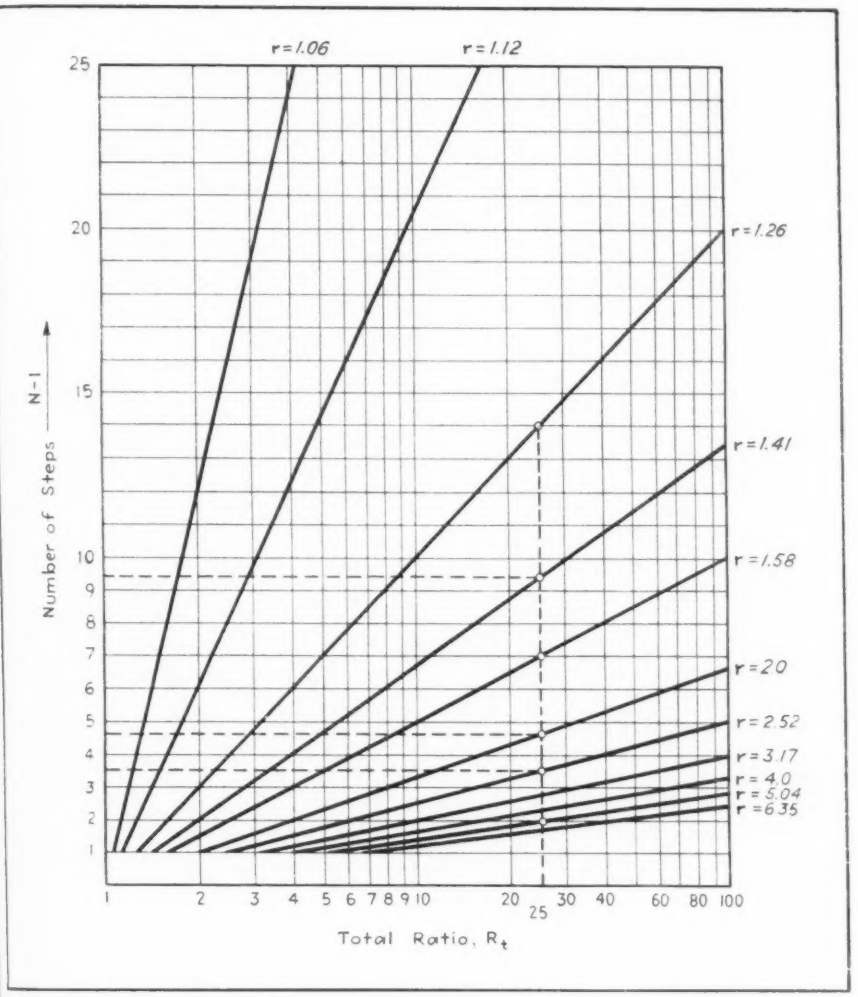


Fig. 2—Number of steps required in a Decimal Geometric Progression series to obtain a given total ratio with a selected single step ratio. See Table I for single step ratios.

Table I—Single Step Ratios Based on Powers of $\sqrt{10}$

$\sqrt[40]{10}$	= 1.06 =	$\sqrt[12]{2}$
$\sqrt[20]{10}$	= 1.12 =	$\sqrt[6]{2}$
$\sqrt[10]{10}$	= 1.26 =	$\sqrt[3]{2}$
$\sqrt[8]{10}$	= 1.41 =	$\sqrt{2}$
$\sqrt[10]{10^2}$	= 1.58 =	$\sqrt[3]{2^2}$
$\sqrt[10]{10^3}$	= 2.00 =	$\sqrt[3]{2^3}$
$\sqrt[10]{10^4}$	= 2.52 =	$\sqrt[3]{2^4}$
$\sqrt[10]{10^5}$	= 3.17 =	$\sqrt[3]{2^5}$
$\sqrt[10]{10^6}$	= 4.00 =	$\sqrt[3]{2^6}$
$\sqrt[10]{10^7}$	= 5.04 =	$\sqrt[3]{2^7}$
$\sqrt[10]{10^8}$	= 6.35 =	$\sqrt[3]{2^8}$

Table II—Practical Subdivisions of Gear Trains

Total Speeds of Gear Train, n	Practical Subdivision	Approx. Number of Gears in Train
2	1×2	4
3	1×3	6
4	2×2	8
6	2×3	10
8	2×2×2	12
9	3×3	12
12	2×2×3	14
16	2×2×2×2	16
18	2×3×3	16
24	2×2×2×3	18
27	3×3×3	18
32	2×2×2×4	20
36	2×2×3×3	20

speed range comprises the ratios of

1.06, 1.12, 1.26, 1.41, 1.58, 2.00

The D.G.P. has also provided the basis for the standardization of revolutions adopted in 1932 by most European countries during Milano Convention.

In a gear train in which

N_i = rpm of input shaft
N_o = rpm of output shaft
n = number of speeds in train
$n-1$ = number of speed steps in train
$r_1, r_2, r_3 \ldots r_{n-1}$ = single ratio of individual pairs of mating gears

the total ratio R_t of the gear train is the product of the several single ratios, that is,

$$R_t = N_i/N_o = r_1 \times r_2 \times r_3 \times \ldots\ldots \times r_{n-1} \quad (1)$$

When the single ratios of individual pairs are all of one value r throughout the train, that is, when

$$r_1 = r,\ r_2 = r,\ r_3, = r,\ r_{n-1} = r$$

then Eq (1) becomes

$$R_t = r^{n-1}, \text{ or } r = \sqrt[n-1]{R_t} \quad (2)$$

or

$$\log R_t = (n-1) \log r \quad (3)$$

A nomograph of Eq (3), shown in Fig. 2, employing the sets of values for r given in Table I, affords a quick and easy method of obtaining the number of steps required for a given total ratio R_t and a selected single ratio r. For example: Assume that a total ratio 1 to 25 is demanded and the single ratio 1 to 1.58 is selected; by tracing to the left from the point of intersection of the ordinate 25 with the single ratio-line 1.58, the number of steps required is found to be 7. When the point of intersection falls between two steps (as seen on ratio-line 1.41), then the next higher or lower number of steps must be selected, and corresponding adjustments made either in the number of revolutions or in the single ratio selected. In similar manner, the total ratio R_t can be found when the number of speeds n and the single step ratio r are given.

Subdivision of Gear Trains

While this method of quickly ascertaining the possible total ratio and number of steps is generally helpful, in practice several limiting considerations reduce the number and range of total steps to a few. One limiting consideration is the restricted number of gears a cluster of sliding gears may contain, when an efficient gear train is the objective. The most useful numbers of gears is 2 and 3, and rarely 4. If the gear train is to be economical, the total of speeds is limited to the product of the number of pairs of mating gears in each speed change subdivision. In Table II are given the practical number of pairs of mating gears per speed change subdivision for gear trains of several total speeds.

Significant equations are formed by setting the total number of speeds, as given in Table II, equal to the product of the factors as given in the second column. For example, in the equation

$$12 = 2 \times 2 \times 3$$

the right side of the equation is to be interpreted thus: The number of factors greater than one equals the number of subdivisions of the gear train, and the numerical value of each factor equals

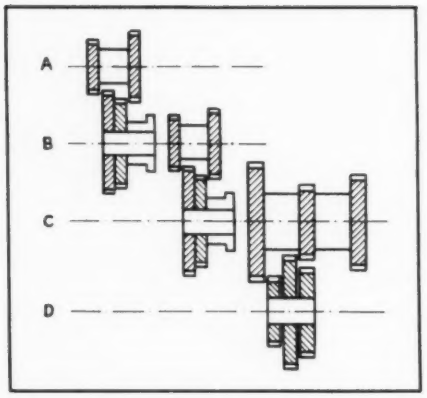


Fig. 3—Three subdivisions of 2, 2 and 3 pairs of mating gears gives final speeds.

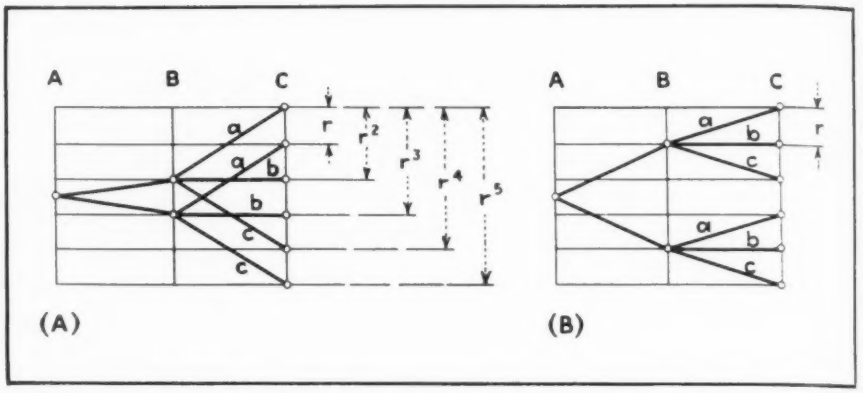


Fig. 4—Graphs of steps showing relation of single speed step ratios in a train. Capital letters designate shafts. Final speeds are the same. (A) Closed form. (B) Open form.

the number of speeds of the respective subdivision. As shown in Fig. 3, the sequence of factors from left to right indicates the sequence of steps from the input to the output shafts.

Graph of Steps

The preliminary analysis of a contemplated gear train will be facilitated by the delineation of the single steps in their proper relationship and proportions. This is accomplished by a Graph of Steps (ascribed to R. Germar), Fig. 4, obtained by drawing as many horizontal lines, separated by equal distances, as there are final single speeds; and as many vertical lines, separated by equal distances, as there are shafts in the gear train. The shaft or vertical lines are designated by capital letters. The single steps between shafts are indicated by a beam or ray; subdivisions of a step are indicated by parallel beams.

The steps shown in the open form of graph, Fig. 4 (*B*) will result in the same final speeds as that of the closed form of graph Fig 4(*A*). These are the only forms possible, since the parallelism of the lines *a, b,* and *c* must be maintained. Which of the two graphs will lead to the best gear train? As a rule it is the closed graph, in contrast to the open form, that results in a more efficient gear train.

Graph of Revolutions

The graph of steps, which clarifies the relationship of the single steps, obviously is not sufficient to appraise the characteristics of a specific gear train. To determine the soundness of a gear train the Graph of Revolutions (also ascribed to R. Germar), Fig. 5, is a helpful device. The construction of this graph is similar to that of the graph of steps insofar as the ratio-lines and shaft-lines are concerned. But the single steps are drawn in to show not only their proper relationship but also their correct magnitude, thus giving the correct value of the revolutions of each shaft of the gear train. From a graph of revolutions, a complete picture of the gear train can be envisaged that gives a clear and comprehensive view of speeds and ratios. This scheme permits a preliminary appraisal of the soundness of the gear train before extensive designing is commenced. In addition, the graph can be extended to include a tabulation of pertinent information such as: Torque at each shaft, pitch line velocity, and tooth load.

The method of finding the smallest aggregate number of teeth T for a given ratio and a pitch diameter difference equivalent to four teeth can best be shown by an example. The following procedure is generally ascribed to J. Androuin and can be employed in most designs with good results.

Assume that the gear train requires the two ratios

$$r_1 = 1/1.41 \qquad \text{and } r_2 = 1/2$$

and that

$$t_3 = t_1 - 4 \qquad \text{and } t_4 = t_2 + 4$$

then where

t = number of teeth in single gear
T = aggregate number of teeth in mating pairs

$$\frac{t_1}{t_2} = \frac{1}{1.41} \text{ and } \frac{t_3}{t_4} = \frac{t_1 - 4}{t_2 + 4} = \frac{1}{2}$$

then solving the two simultaneous equations

$$t_1 = \frac{12}{0.59} \leqq 20 \text{ teeth}$$

$$t_2 = 1.41\, t_1 \leqq 28 \text{ teeth}$$
$$t_3 = t_1 - 4 = 16 \text{ teeth}$$
$$t_4 = t_2 + 4 = 32 \text{ teeth}$$

then

$$T = t_1 + t_2 = t_3 + t_4$$
$$= 20 + 28 = 16 + 32 = 48$$

As will be noted t_3 equals 16 teeth, which is less than the recommended minimum number of teeth of 20. A corresponding larger number of aggregate teeth, which would correct this deficiency, can be obtained by making t_3 equal 20 or more teeth, that is an increase of 25 percent or more, and increasing t_1, t_2, t_4 and T in the same proportion. By making t_3 equal 20, an increase of 25 percent, there results,

$$T = 25 + 35 = 20 + 40 = 60 \text{ teeth}$$

for which the single ratios are

$$r_1 = t_1/t_2 = 25/35 = 5/7 = 1:1.40$$
$$r_2 = t_3/t_4 = 20/40 = 1/2$$

The resulting single ratio r_1 is slightly greater than that stated as required.

This method of calculating smallest aggregate number of teeth is not applicable when the divergency between ratio r_1 and r_2 approaches zero.

Computation of Gear Trains

An example will serve to show how to apply these rules to the design of a gear train.

Example: The gear train shown in Fig. 6 has an input speed of 1,750 rpm. The input speed is to be reduced to 695 rpm, by a pair of gears having a ratio of 2.52. Number of final speeds n required is 9. Highest final speed N_h is to be 695 rpm, and lowest final speed N_l is to be 110 rpm.

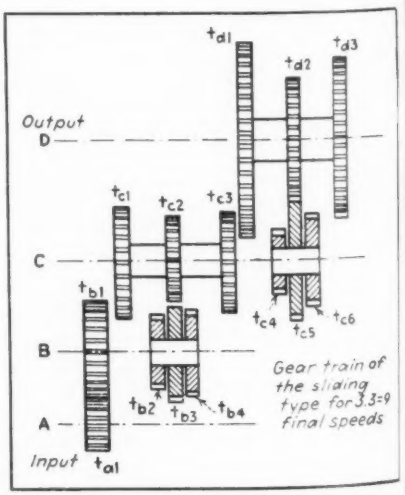


Fig. 6—Arrangement of sliding type gear train to obtain nine final output speeds.

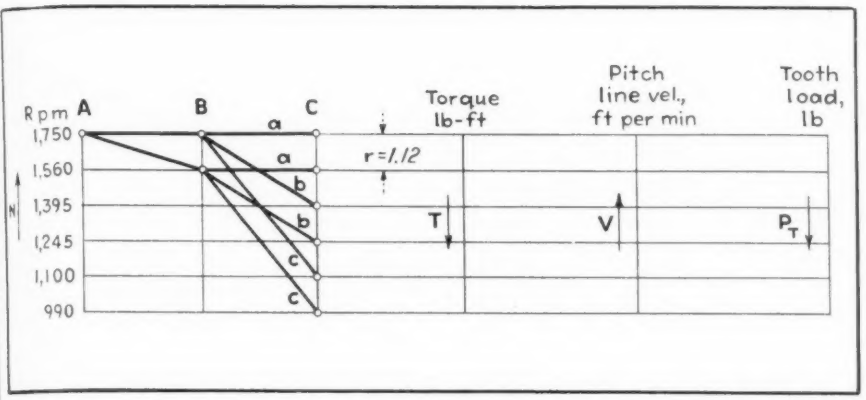


Fig. 5—Graph of revolutions gives a clear and comprehensive view of magnitude of ratios and revolutions. Graph is extended to tabulate other data needed in design of gears.

The total ratio R_T, therefore, is

$R_T = N_h/N_1 = 695/110 = 6.32$

Number of speed steps is

$n - 1 = 9 - 1 = 8$

In the nomograph, Fig. 2, for 8 steps and a total ratio of 6.3, a single ratio r of 1.26 is given. Using this value of r, an adjusted value of R_T is obtained thus

$R_T = r^{n-1} = 1.26^8 = 6.352$

then N_l is adjusted thus

$N_l = 695/6.35 = 109$ rpm

From Table II, the subdivision

$3 \times 3 = 9$

is selected for a gear train of 9 final speeds.

A graph of steps, Fig. 7(*A*), is then drawn, from which the graph of revolutions, Fig. 7(*B*), is obtained.

The graph of revolutions, Fig. 7(*B*), indicates that an economical energy transmission has been attained. The first subdivision, which lies between shafts *B* and *C*, covers a narrow speed range. Hence, the difference in the torques transmitted is relatively small so that there is no great difference in the torsional deflection of shaft *C* or the gears from step to step. Also no energy consuming acceleration of gears and shafts has been employed. In sliding type gears when the single ratios differ greatly in magnitude, a ratio of acceleration might be acceptable when available space is limited. This compromise will probably result in a train having a less favorable energy transmission.

Employing Androuin's method for the first subdivision:

When

$$r_{bc1} = \frac{t_{b2}}{t_{c1}} = \frac{1}{1.26^2} = \frac{1}{1.58}$$

$$r_{bc2} = \frac{t_{b3}}{t_{c2}} = \frac{1}{1}$$

$$r_{bc3} = \frac{t_{b4}}{t_{c3}} = \frac{t_{b2} + 4}{t_{c1} - 4} = \frac{1}{1.26}$$

then

$t_{c1} = 1.58\ t_{b2}$; $t_{c2} = t_{b3}$; and $t_{c3} = 1.26\ t_{b4}$

and

$t_{c1} - 4 = 1.26\ (t_{b2} + 4)$

solving these equations there results

$t_{b2} = 28$ teeth, and $t_{c1} = 44$ teeth

$t_{b4} = 32$ teeth, and $t_{c3} = 40$ teeth

$T_1 = 28 + 44 = 32 + 40 = 72$ teeth

$t_{b2} = t_{c1} = 36$ teeth

The range of usefulness of Androuin's method is confined to ratios the magnitude of which differ at least by 15 percent and that are not in proximity of a 1/1 ratio. It is always advisable, therefore, to check the findings of one method with that of another, and thus be assured that the number of teeth obtained is the most economical.

Another procedure by which a favorable aggregate number of teeth can be found is Schlesinger's method. By this method the first subdivision is obtained by expressing each ratio in numbers such that the numerical sum of the numerator and the denominator is factorable by multiples of 2 and 3. A favorable aggregate number of teeth is a multiple of the product of the factors included in the largest sum. Thus when

$$r_{bc2} = \frac{1}{1}\ ; r_{bc3} = \frac{1}{1.26} \text{ and } r_{bc1} = \frac{1}{1.58}$$

$$r_{bc2} = \frac{1}{1}\text{, and } 1 + 1 = 2 = \qquad 2$$

$$r_{bc3} = \frac{1}{1.26} \cong \frac{4}{5}\text{, and } 4 + 5 = 9 = 3 \times 3$$

$$r_{bc1} = \frac{1}{1.58} \cong \frac{7}{11}\text{, and } 7 + 11 = 18 = 2 \times 3 \times 3$$

A favorable aggregate number of teeth for the mating gears in the first subdivision would be

$3 \times 18 = 54$, and $4 \times 18 = 72$

This checks with the results as obtained by Androuin's method.

With 36 teeth in gear t_{b3}, and gear t_{c2}, the center distance between shafts *B* and *C* is 36 teeth. To avoid interference, therefore, between gear t_{b1} and shaft *C*, gear t_{b1} should have fewer than 72 teeth. The required ratio t_{b1}/t_{a1} equals 2.52, can be obtained by

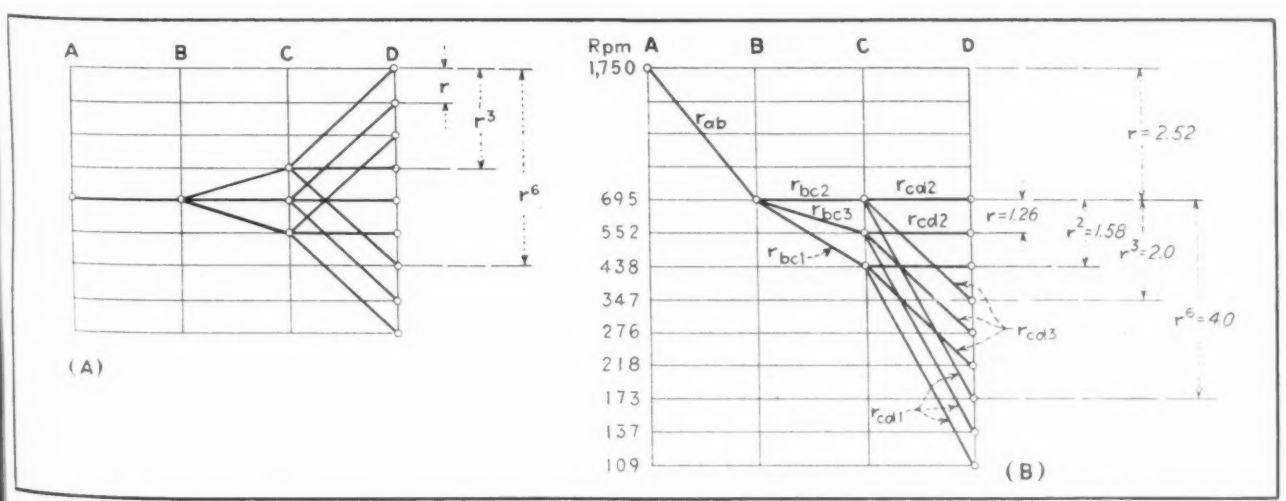


Fig. 7—Graphs for gear train given in Example. (A) Graph of steps showing relation of single speed step ratios in the train. (B) Graph of revolutions. Graph of revolutions indicates that energy is transmitted economically from shaft to shaft.

using 63 teeth in gear t_{b1} and 25 teeth in gear t_{a1}, the input gear.

For the second subdivision the ratios are:

$$r_{cd1} = \frac{t_{c4}}{t_{d1}} = \frac{1}{1.26^6} = \frac{1}{4}$$

$$r_{cd2} = \frac{t_{c5}}{t_{d2}} = \frac{1}{1}$$

$$r_{cd3} = \frac{t_{c6}}{t_{d3}} = \frac{t_{c4} + 4}{t_{d1} - 4} = \frac{1}{1.26^3} = \frac{1}{2}$$

then for trial values

$t_{d1} = 4t_{c4}$; $t_{d2} = t_{c5}$; $t_{d3} = 2t_{c6}$
and $t_{d1} - 4 = 2\,(t_{c4} + 4)$

or

$t_{c4} = 6$ teeth, and $t_{d1} = 24$ teeth
$t_{c6} = 10$ teeth, and $t_{d3} = 20$ teeth
$T_2 = 6 + 24 = 10 + 20 = 30$ teeth
$t_{c5} = t_{d2} = 15$ teeth

Retaining the rule not to use a gear with less than 20 teeth and also to avoid possible interference between shaft B and gear t_{c5} that are at a center distance of 36 teeth, gear t_{c4} should have 20 or more teeth and gear t_{c5} should have not more than 60 teeth. Hence 100 is selected for T_2 and the teeth in each gear are adjusted by multiplying each trial value by 100/30. The results will then be

$t_{c4} = 20$ teeth, and $t_{d1} = 80$ teeth
$t_{c6} = 33$ teeth, and $t_{d3} = 67$ teeth
$T_2 = 20 + 80 = 33 + 67 = 100$ teeth
$t_{c5} = t_{d2} = 50$ teeth

The final speeds given in Table III will be obtained by using the foregoing values for numbers of teeth in the respective gears. The speeds are substantially in agreement with the desired speed ratios and deviate only slightly from the desired decimal geometric progression of the successive speeds.

Table III—Final Speeds and Desired Speeds

Final Speeds, rpm	Desired Progression, rpm	Final Speeds, rpm	Desired Progression, rpm
695	695	218	218
556	551	174	173
442	437	139	137
343	347	111	109
274	275		

REFERENCES

1. Speeds and Feeds of Machine Tools: Carl G. Barth, *American Machinist*, Jan. 11, 1912.

2. Geometric Progression of Speeds in Machine Tools: C. C. Stutz, *American Machinist*, Jan. 15, 1920.

3. Beitrag zur Theorie der Stufenraedergetriebe: Kryspin-Exner, Werksattstechnik, 1925, page 757.

4. Ueber Theorie and Bestimmung der Zaehnezahlen in Getrieben mit Geometrisch abgestuften Drehzahlen: K. Bennedik, *V.D.I.*, Vol. 74, 1930, page 1057.

5. Einheitliche Drehzahlreihen fuer Drehbaenke: G. Schlesinger, *V.D.I.*, 1930, page 1509.

7. Gear Trains for Changeable Speed Ratios: J. A. Hall, PRODUCT ENGINEERING, Feb. and March 1934.

8. Proposed American Standard Preferred Numbers. *American Machinist*, Nov. 7, 1934.

9. Determination of Change Gears. F. Lancaster, *American Machinist*, Nov. 7, 1934.

10. Die Berechnung von Zahnradgetrieben. A. Wallichs and H. S. Schoepke, *V.D.I.*, Feb. 1936.

11. Theorie et Technologie des Engrenages. Vol. 3. *Les Transmissions par Engrenages*. J. Perignon, Paris, Dunod, 1936.

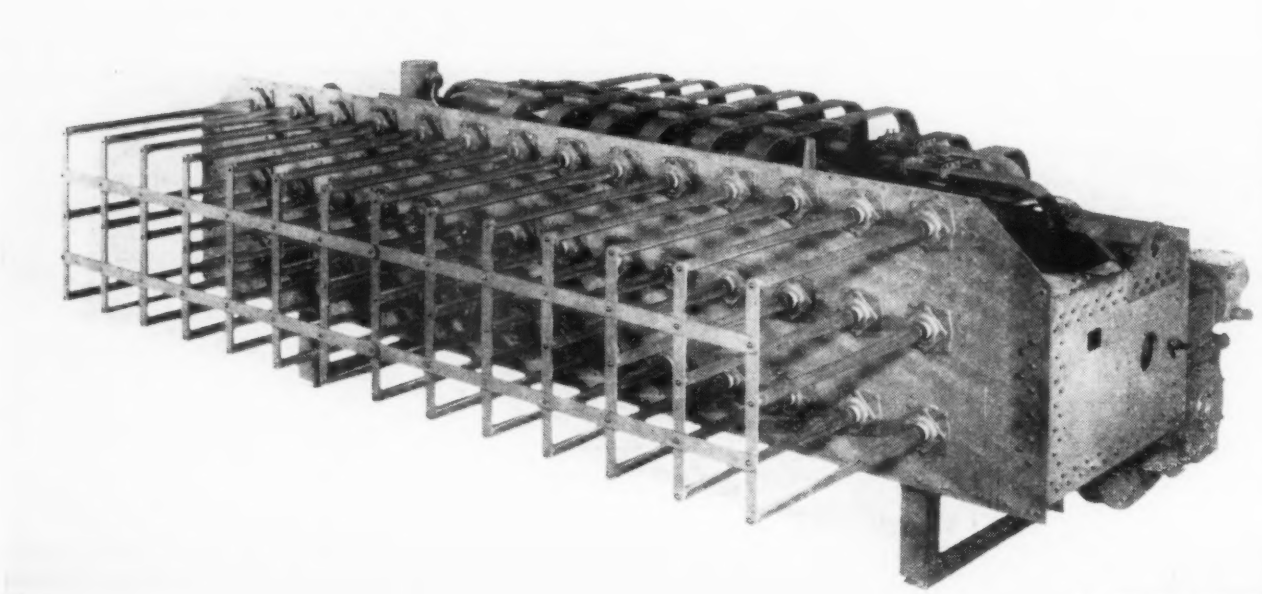
Plastics Used in Fire Control Radar Antenna

LIKE A GIANT PIN-CUSHION, this U. S. Navy fire control radar antenna contains an array of polystyrene rods that provided much needed rapid scanning qualities. Radio beams of early models had large angular coverage and could not separate distant objects rapidly or accurately.

The antenna developed by Bell Telephone Laboratories is a horizontal array of 14 identical fixed elements, each a vertical array of three tapered polystyrene rods. When inserted into the open end of a wave guide, these rods radiate energy from points distributed continuously along their length. The rod radiates along its length because of its taper and because of discontinuity produced between the plastic and surrounding air.

Phase control is established by 13 rotary phase changers in the distributing system. Each phase changer rotates continuously and produces a beam that sweeps repeatedly linearly across the sector to be scanned.

Radiation pattern of the rods has a shape characteristic of end fire arrays and can be fitted in well with the array factor for rapid scanning. That this antenna was effective can be proved by scores of Japanese hulls, victims of uncanny accuracy of fire control.



Bell Telephone Laboratories

NEW BOOKS

Industrial Applications of Infrared

JAMES DOYLE HALL, *Advisory Engineer, Lamp Division, Westinghouse Electric Corporation.* 201 *pages,* 6¼ x 9 1/6 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W. 42nd St., New York* 18, *N. Y.* $3.50.

A compilation of information on infrared heat applied to industrial problems. Theory is included, along with data from many installations. Both incandescent lamps and radiant-heat lamps are discussed as sources of infrared radiation. Chapter V covers the planning and designing of an infrared installation. Special problems such as heating three-dimensional objects, radiation of materials having high infrared reflectivity and the heat processing of highly explosive volatiles are included in Chapter VI. Drying of surface finishes, textiles, processing of ceramics, and the manufacture of plastics and paper are discussed in Chapter VII. The last chapter covers therapeutic, photographic, plant protection and insect extermination uses. The book is written for the engineer who wishes to investigate infrared for his particular problem.

An Introduction to Metallurgy

JOSEPH NEWTON, *Professor of Metallurgy, University of Idaho. Second Edition.* 645 *pages,* 6¼ x 9⅛ *in. Published by John Wiley & Sons, Inc.,* 440 *Fourth Ave., New York* 16, *N. Y.* $5.50.

Presents an introduction to the field of metallurgy as a foundation upon which the student can build advanced and specialized studies. Two divisions, "Adaptive Metallurgy" and "Extractive Metallurgy," comprise the text. Each chapter has examples of typical calculations, a list of exercises, and a short reading list.

College Technical Physics

ROBERT L. WEBER, MARSH W. WHITE, KENNETH V. MANNING, *all of Pennsylvania State College. First edition* 761 *pages,* 9 x 6 *in. Published by the McGraw-Hill Book Co. Inc.,* 330 *W. 42nd St., New York* 18, *N. Y.* $4.50.

A well-organized book that covers the basic ideas of physics for students of science and engineering at the college level. It is distinctly a first year course, but the authors have been careful to include the widest range of physics. Heat transfer and acoustics, for example, are more thoroughly covered than is usual in an elementary text. The usefulness of the book is increased by the appendix, which gives advice to the student on the solution of physical problems, the determination of significant figures in calculation, and fundamentals of trigonometry. Drawings of Nobel prize winners appear as chapter headpieces.

The Blueprint Language

HENRY C. SPENCER, *Professor Technical Drawing, Illinois Institute of Technology;* HIRAM E. GRANT, *Associate Professor Engineering Drawing, Washington University.* 255 *pages,* 9½ x 11½ *in. Published by the Macmillan Co., 60 Fifth Ave., New York.* $5.

The authors have endeavored to provide a thoroughly practical book to give untrained men and women a fundamental training in blueprint reading. This requires visualization of views of the object, and also worksheets are provided after each chapter to give the students training in applying the text information. Chapter topics include industrial prints, views of objects, normal surfaces, inclined and oblique surfaces and edges, cylindrical surfaces and edges, sectional views, auxiliary views, screw threads, dimensioning practice and shop processes. A useful chapter tells how to read micrometer, calipers and high gages. Another interesting chapter discusses gears, so that the untrained person could acquire a respectable acquaintance with gear dimensions.

Theory and Application of Radio-Frequency Heating

GEORGE H. BROWN *and* CYRIL N. HOYLER, *research engineers of RCA Laboratories and* RUDOLPH A. BIERWIRTH, *chief engineer, Sound Incorporated.* 370 *pages.* 6¼ x 9¼ *in. Published by D. Van Nostrand Co. Inc.,* 250 *Fourth Ave., New York, N. Y.* $6.50.

Volume is aimed at industrial engineers who may wish to use radio-frequency for heating. The 24 chapters include discussions of current flow and distribution in variety of conductors and sheets, efficiency of heating coils, heat flow relationships, annealing nonferrous metals, case hardening of steel, radio frequency heating of poor electrical conductors, wood gluing, r-f sewing machine, dehydration and treatment of food.

More than 260 illustrations are used. Where mathematical derivations are made throughout the text, graphical displays are used to convey the conclusions that were reached by analytical means. The principles are illustrated by experimental data and often by a description of a complete laboratory experiment Some of these experiments resulted in the design and installation of industrial equipment. Many others are awaiting future exploitation, while a number of the experiments were solely for the establishment of certain principles and the accumulation of knowledge for helping solve problems yet unpropounded.

An Introduction to Engineering Plastics

D. WARBURTON BROWN *and* WILBUR T. HARRIS. 274 *pages,* 6¼ *x* 9¼ *in. Published by Murray Hill Books, Inc.,* 232 *Madison Ave., New York* 16, *N. Y.* $4.

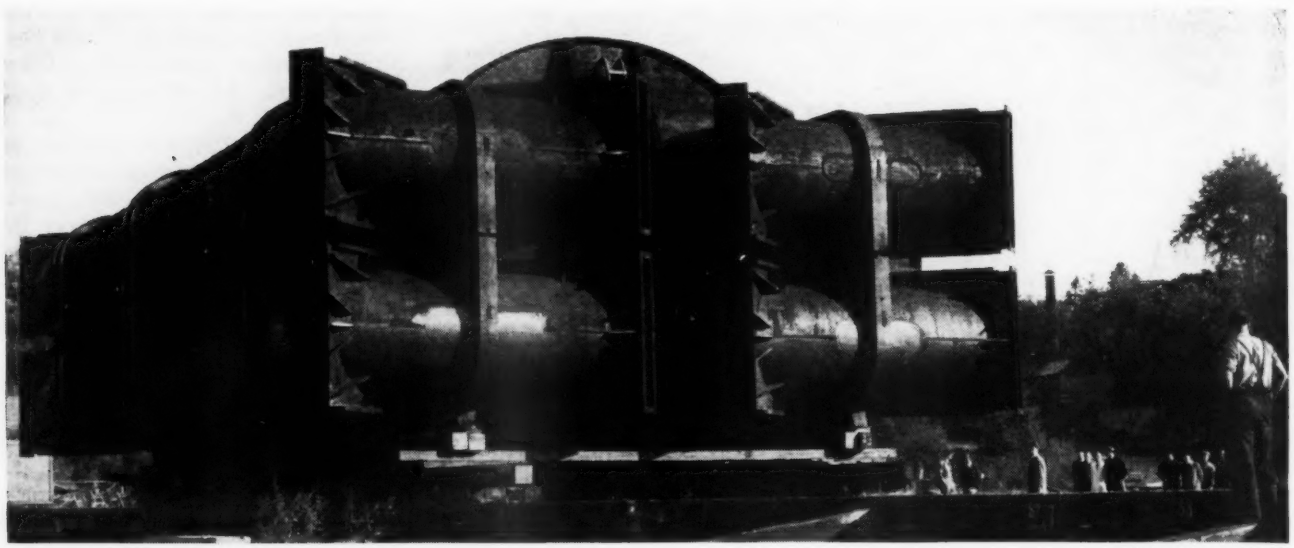
This is a presentation of plastics that have found commercial acceptance. Included are chapters on the engineering properties, chemical resistance and applications of plastics. Techniques in handling plastics are covered. Plastics materials, their tradenames and manufacturers are listed.

Tungsten, A. C. S. Monograph No. 94

K. C. LI, *Chief Engineer, and* CHUNG YU WANG, *Director of Research, both of the National Reconditioning Company, Inc., New York. Second Edition, revised and enlarged.* 430 *pages,* 6¼ *x* 9¼ *in. Published by Reinhold Publishing Corp.,* 330 *W. 42nd St., New York* 18, *N. Y.* $8.50.

This American Chemical Society Monograph is an exhaustive study designed to bring together all the knowledge on tungsten. It is so presented as to be intelligible to workers in many fields, and it is a digest of progress to date. It serves to point out the direction for subsequent investigations. Included are geology, ore dressing, metallurgy, chemistry, analysis, and many industrial applications.

TECHNICAL NEWS HIGHLIGHTS



Vickers-Armstrongs Ltd.

LARGEST STRATOSPHERE TEST CHAMBER in the world, 215 tons, 40,000 cu ft, will be capable of reproducing conditions at any altitude to 70,000 feet. Low temperature or altitude tests can be made on full-scale airplane fuselages.

Research in Britain Sponsored by Government

Private industry cooperates with government to further basic research under limitations of austerity economy and manpower shortage.

AN INTEGRATED RESEARCH POLICY, with government support as its keystone, is being developed in Great Britain. Within limits of available manpower and overcrowded facilities, no single field of fundamental or applied research is being overlooked. Fundamental research, long a concern of British government, has been actively supported since the first world war.

Although emphasis is now placed on fundamental research, applied research and development will take positions of increasing importance. The war disrupted all research and the British feel they can best serve their needs by first rebuilding in the familiar field of fundamental research.

This emphasis on basic research has led to a system of research priorities. For military needs, top priority has been given to projects for application twenty years hence. Paradoxically, more immediate projects are being pursued with less urgency.

Civilian research projects are almost free from priorities. There is an interdepartmental government committee that exercises control necessary to best use available resources.

TYPES OF PROJECTS

Judged by total money outlay, nuclear physics and related application research get the largest support. Highest strategic importance is attached to this research.

Outstanding among the planned government units already approved are a model basin for studying hydraulics, comparable to the work at the U. S. Navy's David Taylor Model Basin; and a Mechanical Engineering Research Station. The latter is a recently organized project for fundamental work in mechanical engineering and will be finally located in Scotland to conform with plans for decentralization of industry and research.

Within four or five years, a completely new National Gas Turbine Establishment will be constructed. As with all research planning, this building program will depend on availability of materials and construction workers.

Scotland will also furnish the sites for three new sub-stations in building research, road research and fuel research.

The latter project, increasing efficiency of fuel consumption, is vital to the British economy. England, long able to export coal, is now faced with a serious shortage of fuel. Domestic heating plants appear to offer greatest room for improvement and are receiving most effort. However, industrial power plants, such as locomotives, stationary plants and processing equipment, will also be vitally affected by this research.

PRIVATE RESEARCH

Private industry has many plans for enlarging research facilities and several companies have already completed initial phases of their programs. As would appear natural, two noteworthy examples are in the aircraft field. Vickers-Armstrongs has just completed construction of a 40,000 cu ft altitude chamber for flight research, believed to be the largest of its kind. Another aircraft firm, the De Havilland Aircraft Company, has put in service another type of altitude chamber, which can simulate a wide range of service conditions.

Capable of holding a large section of a transport fuselage, or a complete fighter fuselage, the De Havilland altitude test chamber has simulated altitudes of 80,000 ft in its 12 ft dia, 27 ft long working space. Since conditions of pressure, temperature, rate of climb and humidity can be duplicated, the chamber will aid in design of high altitude planes to meet requirements of passenger comfort and structural strength.

The main chamber is evacuated by

a 2,000 cfm capacity, double-acting, single cylinder vacuum pump driven by an electric motor. When refrigeration is necessary, a system using methylated spirit sprayed over crushed blocks of dry ice is used. Inside air can be heated to +40 C with a steam heater to duplicate tropical conditions.

A smaller chamber in the De Havilland set-up, suitable for tests on aircraft fuel systems and small auxiliary equipment, is connected to the main chamber vacuum pump and can be evacuated to the same altitudes as the main chamber. Refrigeration is not needed for this chamber but provision is included for future installation.

Test runs on fuselages are handled by a team of twenty men—stress plotters, structural test engineers, strain gage technicians—under control of the test engineer. As pressure differential is increased pound by pound, it is stabilized by the controller and the physical condition of the fuselage skin is double checked.

If part of the structure begins to give way through local weakness, loss of cabin pressure is immediately noted and pressure differential is reduced. The second check is made by patch-type strain gages connected to a cine regarding oscilloscope. If strain does not increase uniformly, pressure differential can be reduced and point of local weakness will be noted.

Final safeguard against sudden failure is provided by a microphone that picks up any sound of breaking structure and warns the controller in time to prevent complete collapse.

Differential pressure tests with the De Havilland chamber will provide structural design information; temperature and humidity tests will provide information to insure passenger comfort and crew efficiency.

Companies that expanded research capacities just prior to the war are again in need of more space. Curtailment or postponement of capital expenditures, details of which are still being worked out, make private industry plans indefinite at this time.

Fully as important as plans for new buildings are measures being taken to double the number of scientifically-trained personnel. Great Britain has 55,000 men trained for scientific work, not all actively engaged in research, and will try to increase this number to 99,000, as recommended by a special government committee in 1944.

Of the 44,000 men needed to comply with the total figure recommended by the committee, private industrial establishments require 2,500. Most widely in demand are chemists, nearly 900; electrical, aeronautical, automotive and other engineers, over 500; and about 275 physicists.

In efforts to obtain this number of researchers, grants to universities will be increased and fellowships will be made more attractive. But British universities are as crowded as American schools and efforts to increase enrollment also depend on building material shortages. Added teaching burden on professors reduces their available research time and thus reduces present results.

Still another problem is arising to effect university enrollment; universal military training. While science students can elect to defer their year of military training until they have finished their schooling, short-term effects will just about counterbalance increased enrollment.

Upon successfully demonstrating their future usefulness to the research program, young graduates can be "reserved" from training by a board of selectors. In many cases the man has not progressed far enough in his profession to demonstrate his ability before he is again subject to call. He is lost to research for at least the year of his service, and possibly forever if his interests have been changed.

British Official Potoghraph

TOP BRITISH Ionosphere Researcher, Sir Edward Appleton, 1947 Nobel Prize-winner, holds the senior British Government post concerned with physical science, Secretary of the Department of Scientific and Industrial Research. He is the discoverer of the "Appleton layer", and his detection of the ionosphere by reflection of radio waves led to important developments in radio and military radar.

British industry is currently spending 30 million pounds ($120,000,000) per year on scientific research. Industry, in general, plans further expansion of research facilities during the next two years. Culmination of plans depends on increased building material production and training of technical personnel to staff the expanded laboratories.

These private industry plans are over and above substantial expenditures for industrial research made by the government. Of 70 million pounds expended by the government for all research and development during the past year, 4.5 million were for industrial research and 60 million for defense research.

Figures for private industry expenditures were compiled by the Federation of British Industries (counterpart of the American NAM) from reports obtained from 420 firms that each spend more than 1,000 pounds per year on research. It is estimated that companies in this group carry out 75 percent of all industrial research in Britain.

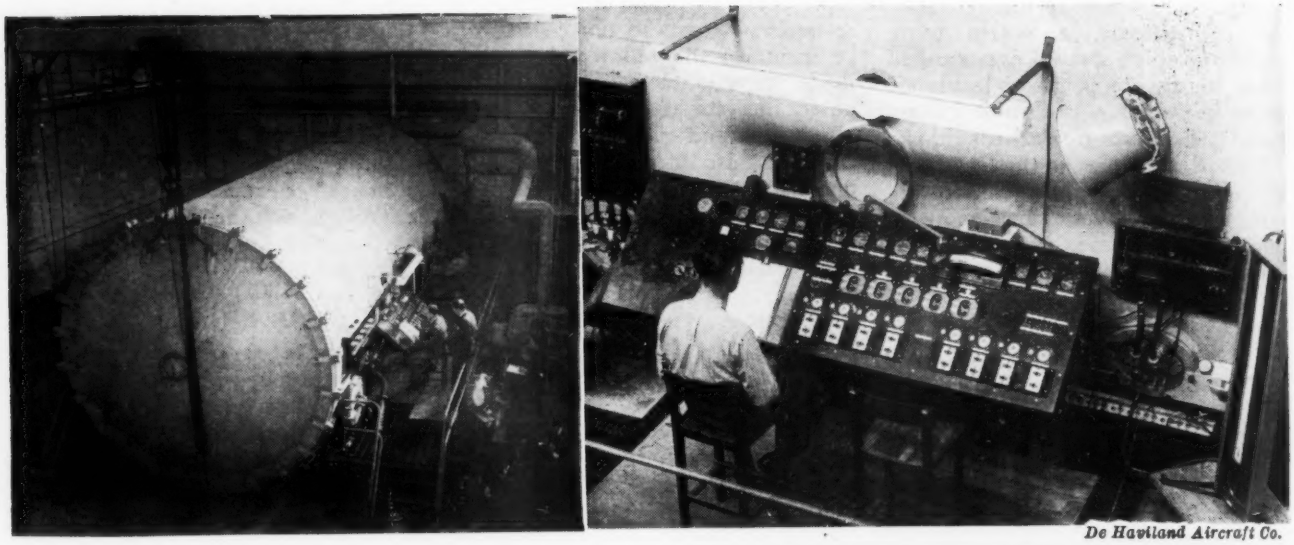
Three out of five reporting firms plan to expand their activities during the next two years, and two of these three have in mind additional research buildings amounting to more than 2,500,000 sq feet. These plans, though approved by the companies, have yet to be reviewed by the government, in accordance with the present restrictions on capital expenditures.

Research Control

In Britain, the government acts both as sponsor and conductor of almost all fundamental research. For much applied research, in early stages, it also acts as sponsor, auditor and interested customer. Details of direction, execution and application are largely left in non-governmental hands.

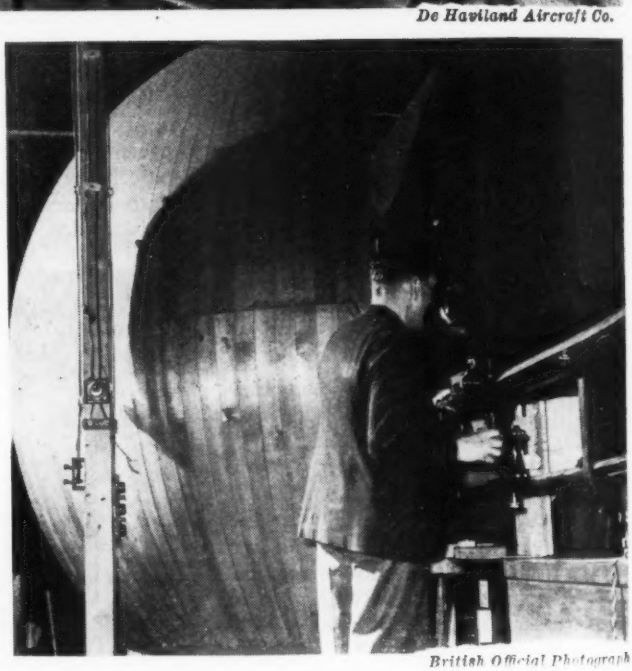
British research organization, under a separate government department has recently been revamped, to emerge with "a new research charter". Direction, both of research policy and administration, has practically returned to civilian control. These changes are said to have included many recommendations similar to those offered to President Truman by the Steelman Committee (see Product Engineering, October 1947, page 151).

Civilians are in the majority on the newly-established Advisory Committee on Scientific Policy and they could potentially control policy decisions made by the administrator. Because of the link that exists with the post-



De Havilland Aircraft Co.

(Above). High-altitude test chamber can simulate conditions at altitudes to 70,000 ft and temperatures of —70 C. Welded steel plate, $\frac{5}{8}$ in. thick, forms 14 ft. dia., 35 ft. long cylindrical shell. Near end of chamber is removbale for insertion of large airplane section. (Upper right) Control panel with loudspeaker for carrying speech from observers working inside chamber. Controller's microphone is mounted on a swinging arm so he can station himself before any group of instruments. Strain gage cables enter chamber through inlet at left of control panel.



British Official Photograph

(Lower right). Largest integrating sphere photometer, this 10 ft diameter "Ulbricht" type instrument is in use at the National Physical Laboratory (similar to the U. S. National Bureau of Standards). Built of wooden segments, the instrument measures total light of a source suspended at the center. Light rays are emitted in all directions and are reflected from white interior wall of sphere so that light emerging from a small aperture is proportional to total light of source. This light is measured by comparison with that emerging from a standard source.

war Defense Research Policy Committee, Sir Henry Tizard, (a specialist in aeronautical sciences), chairman, and Sir Edward Appleton, secretary of the Department of Scientific and Industrial Research, members of both committees, fuller coordination between military and civil research is expected.

Each government department appoints a chief scientific officer who is required to bring before the appropriate advisory committee all projects he contemplates. He is expected to see that findings of all research establishments are fully applied in his department.

Dominance of non-government people in British research has already been responsible for the clarified policy that all university research done for the military services be released from security and made available for publication.

British trade associations are strong sponsors of cooperative research, applied and fundamental. This activity is encouraged by the government and tax-relief is granted to expenditures and contributions for research purposes.

Until recently, there has been no demand in England for a private-industry sponsored cooperative research institute similar to the Battelle Memorial Institute in the United States. Any firm with money to spend on such projects would normally undertake it within its own laboratories, if it wanted to retain the exclusive use of the findings. However, the Fulmer Institute was established during the past summer, for just such work. Sponsored initially by a group of light - metal - products manufacturers, the Institute's first work will be done for them, but research facilities will be available eventually to all industries.

There is only one large privately-endowed foundation sponsoring research, the Nuffield Foundation, established by the head of Britain's large motor car manufacturing firms. It works almost entirely through grants to universities.

The British government has not given its scientists the task of solving the country's drastic economic plight. It is fully realized that the immediate need of the country is to apply, as quickly as possible, the knowledge it already possesses. The government has set itself the task of stimulating all parts of the British economy to make that application.

Washington Notes

President Announces Plan for Federal Research Coordination

Recent announcement of an Interdepartmental Committee for Scientific Research follows a recommendation contained in the report of the President's Scientific Research Board (see PRODUCT ENGINEERING, October, 1947, page 151) headed by John R. Steelman. According to the Steelman report, the purpose of the interdepartmental committee is to set general policies; prevent overlapping of projects between government departments, whenever possible; and maintain a "sensible" balance between different fields of research.

The Committee, which will be purely a study and advisory group, will be made up of representatives from the following agencies: Agriculture, Commerce, Interior, Army, Navy, Air, Federal Security Agency, Atomic Energy Commission, National Advisory Committee for Aeronautics, Veterans Administration and the Smithsonian Institute. A member of the former Steelman committee probably will be appointed for scientific liaison with the White House.

Indications are that the committee will work along lines outlined in the Steelman report. It will study ways to maintain a balance between various government research programs and note where there are apparent gaps. However, it will not actually allocate projects among the various agencies engaged in scientific research.

One of the suggestions contained in the Steelman report was that the Interdepartmental Committee undertake immediately a full analysis of the relative advantages of contracts and grants as a means of supporting research, with recommendations for uniform legislation.

President Truman's statement, in connection with establishment of the Committee, revealed that "there is no central group equipped to advise on the relationships among the numerous and complex Federal scientific activities, or to take leadership in the solution of administrative problems common to different agencies."

According to the President's executive order, the chairman of the Committee will be designated by the President. Specifically, the duties of the Committee will be to:

1. Recommend steps to make the research and development programs of the Federal Government most effective in promotion of national welfare.

2. Study or propose studies and recommend changes in administrative policies and procedures, including personnel policies, designed to increase the efficiency of the Federal research and development program.

3. Study and report on current policies and Federal administrative practices relating to Federal support for research, such as grants and contracts for basic research.

4. Obtain the advice of persons not employed by the Federal Government with respect to matters of concern to the Committee.

5. Encourage collaboration among Federal agencies engaged in related scientific research and development.

6. Propose means by which information relating to the status and results of scientific research and development undertaken or supported by Federal agencies can be most effectively disseminated.

Reactions from scientists have not been forthcoming; they are waiting to learn the personnel makeup of the Committee before expressing initial opinions.

Industry, however, seems to have taken to the idea of an interdepartmental committee. The National Association of Manufacturers has expressed the desire to assist the Pres-

Ram-Jet Helicopter Completes Test Flights

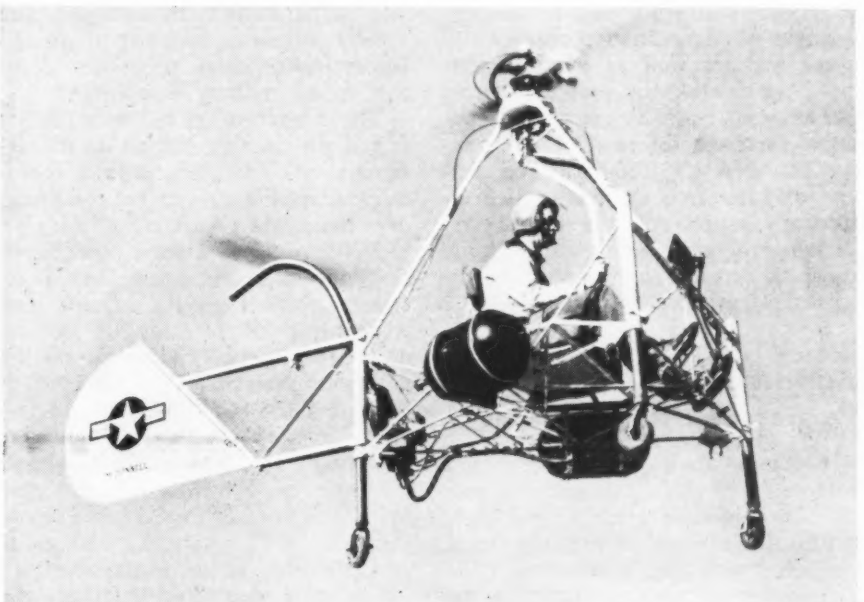
FIRST ROTARY-WING AIRCRAFT ever to employ a ram-jet power plant, the U. S. Air Force's McDonnell helicopter has successfully completed six months of flight testing.

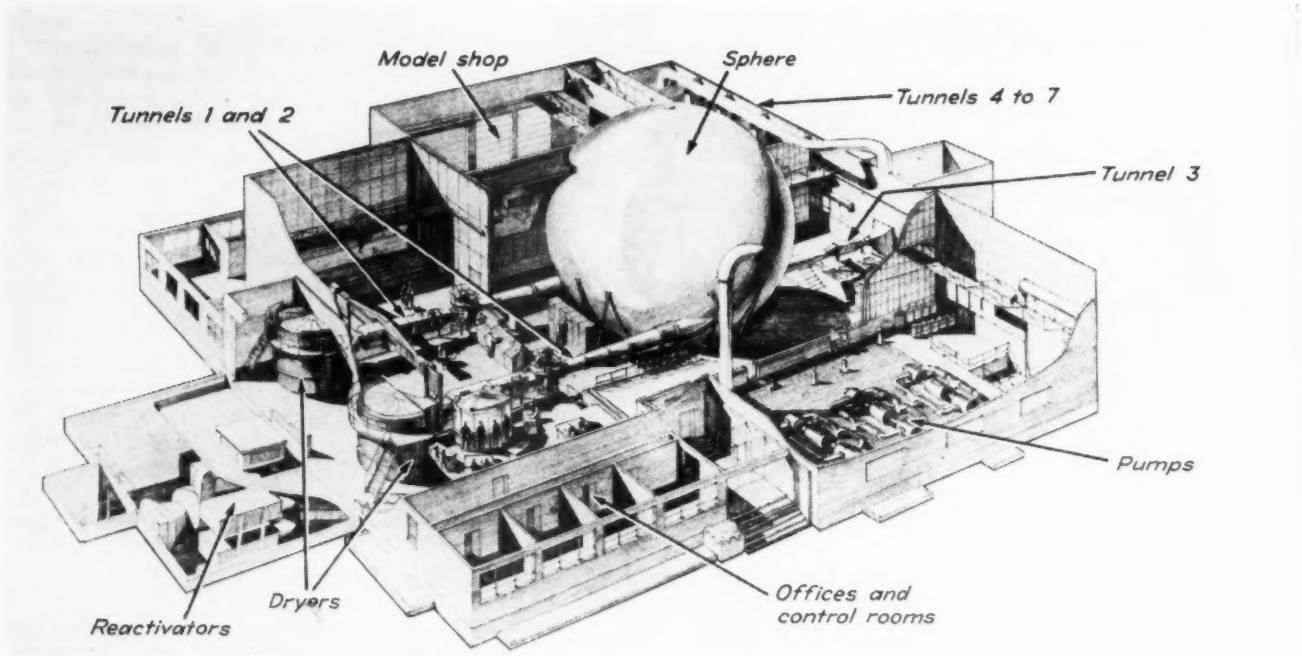
Developed after almost 2 years of research, the ram-jet helicopter is actually a three-dimensional aerial motorcycle. It consists of an all-metal, two-blade rotor, 18 ft in diameter, with a 10 lb ram-jet power unit at each tip, a small rudder, and an open steel tube structure supporting the pilot, fuel tanks and controls. The present configuration is merely a flying test stand intended to prove the basic idea, and no aircraft designation has been given the plane.

Although it weighs only 310 lb, it has lifted a useful load of 300 lb and has attained a forward speed of 50 mph. Since power is applied directly to the blade tips, heavy engine parts, gear systems, and transmissions are unnecessary.

The ram-jet power unit is simple in design, resembling a stove-pipe. Whirling rotor blades ram air into the duct, where it is burned by a fuel mixture injected through the blades. Since the ram-jets function only above 600 fps, an auxiliary starter is required.

Fuel for the power plant has been propane, although gasoline burning ram-jets are under investigation. Two tanks attached to the lower fuselage supply fuel. After initial fuel pressure is built up, centrifugal force provides the necessary pumping action for keeping the system in operation.





SUPERSONIC AERODYNAMICS WILL BE STUDIED in this set of wind tunnels now under construction at the Naval Ordnance Laboratory, White Oak, Maryland. Essentially a reconstruction of the famous Kochel wind tunnels found by American troops in Germany, the tunnels will be useful in the design of bombs, rockets and guided missiles. These tunnels have been considered as far superior to tunnels in other countries; the development of the V-2, involving measurements of supersonic speeds up to Mach No. 4.4, was greatly aided by the tunnels.

One of the most striking features of the Kochel tunnel design is its economy of operation. An ingenious method of intermittent operation makes it possible to operate the tunnels with remarkable efficiency, at a fraction of the power required for a continuous tunnel of comparable size. The tunnels are operated at less than atmospheric pressure. Air is dried by passing through a bed of absorbent material before entering the test section, and discharges from the test section into an evacuated sphere through a discharge line containing the two essential elements of the intermittent system: A second throat, and a quick operating valve.

Test section conditions are characterized by extremely low temperatures and pressures; the velocity of sound in the test section is therefore lower than in air under atmospheric conditions. The velocity of the air relative to sound velocity in the test section is constant and depends only on the relative size of throat and end section of the nozzle. A change of nozzles for different Mach numbers is a simple operation requiring not more than five minutes.

Some modification of the Kochel tunnels is being made. For example, the large motors are being converted to run on 4,000 volts at 60 cycles, while in Germany they operated on 6,000 volts at 50 cycles. Instrumentation includes a Navy-developed optical interferometer and an excellent Schlieren system.

ident's committee as much as possible.

According to Howard E. Blood, chairman of NAM's Patents and Research Committee, the NAM is "especially interested in noting that the committee is to study and recommend changes in administrative policies and procedures, as well as administrative practices relating to federal support for research, such as grants and contracts for basic research.

"The NAM's Committee on Patents and Research also has studied intensively aspects of the Federal research program relating to research contracts between the Federal Government and private contractors."

Army and Navy Research Programs Set for Two Years

Research having immediate and long-term effects on design and production is planned in Army and Navy programs, some of which are being projected well into 1950.

Throughout the Army program, designs leading to air portability are stressed, going beyond those items which would be used by an airborne unit. The requirements of air portability are compactness, lightness, and "simple handling characteristics." The rapidly increasing mobility of ground forces makes these properties desirable in all military equipment.

The advent of global warfare has forced still another burden on the designers: To design standard equipment adaptable to varying conditions over the world's surface.

Increased use of electric power, control, and instrumentation, has accelerated research in the electric and electronic fields, to meet the stiff requirements of space, weight, durability and dependability. The demand is high also for more perfect and less bulky insulation, new prime movers for generators, new electronic voltage, frequency, and current controls, new light weight transformers and more complete, more accurate, and more adaptable fire control mechanisms.

Electronic research will include the propagation of all frequencies, including those little known at present, through extra-terrestrial space; simplification of circuits through the use of a minimum number of parts, each having a maximum number of functions; development of radiating systems, including perfection of the lens type directional antenna; development of simple receivers to cover the entire usable frequency range; simple means of countering the effects of jamming, and more adequate methods of transmission interception.

Infra-red projects include: Development of thermal locating systems capable of detecting and charting the bearings of surface vessels, the conversion of electro-magnetic energy to sonic vibrations, and improvement of the intensity of and persistence of luminous materials, and infra-red phosphors.

There is a definite need for more highpowered weapons in light and medium tanks. The requirements of artillery pieces suited to airborne operations call for longer life, light-

ness, and greater utility. Studies are under way on gun steels to reduce the strategic alloys required and to improve ductility and toughness. Improved one lb, 60 and 400 cycle synchro units are being developed to replace the 5 and 10 lb units used in synchro data transmission between adajacent gun batteries. Structural members made of aluminum and magnesium alloys have been developed; increased longevity of recoil mechanisms is a research goal. The development of fully automatic cannon now includes sizes up to 105 mm, and work is being done to apply power operated loading mechanisms to tanks. In aircraft armament, the trend is toward higher muzzle velocities, higher cyclic rates, and better fire control.

Efforts are being made to improve design of military cameras both for ground and aerial work. Design is being carried out on a 70 mm still combat camera, two different types of precision mapping cameras, special high speed strip cameras with moving film, 70 mm attack cameras for recording low altitude aircraft attacks, 16 mm and 35 mm recording cameras for radar scopes, and stereo strip cameras for low-altitude reconnaisance.

Track-landing gear for aircraft is slated for further testing on various types of planes, under varying conditions. Skiis will be tested on a cargo plane weighing 50,000 to 75,000 lb. Booster type brake assemblies will be tried out on Boeing B-29 and Fairchild C-82 airplanes. Attempts to increase the load capacities of aircraft tires without increasing their size have initiated plans to try nylon tires with extra plies and wire tires. New high speed wings cannot take to present thick standard aircraft tire; new sizes of large diameter will be developed, this cross section is an effort to overcome complex fuselage retraction systems. Attempts will be made to enclose more of the brake in the aircraft wheel.

Where high speeds will be encountered, the effect of high temperatures and heavy loads for long periods will play a leading role in design. The supersonic wind tunnel at the Naval Ordnance Laboratory, White Oak, Md. (see accompanying illustration) is nearing completion and will be capable of producing Mach numbers up to 4.8 for testing models of both aircraft parts and guided missiles.

Naval research in ceramics covers inorganic non-metallic solids, including refractories, electric insulating ceramics and minerals, glass abrasives vitreous enamels, concrete and clay products, and piezo-electric crystals.

Titanium metal is under intensive scrutiny and it has been claimed that it has a tensile strength of 100,000 psi, half the density of iron, and high corrosive resistance.

Research under Office of Naval Research contracts has been started on non-linear direction finding devices, and electromagnetic radiation of radio frequencies from celestial bodies. Super-conductivity and ferro magnetism at microwave frequencies is under close observation. The generation of ultrasonics is now as high as 1,000 megacycles per second, which is especially applicable to target indicator problems and storage requirements in digital computers.

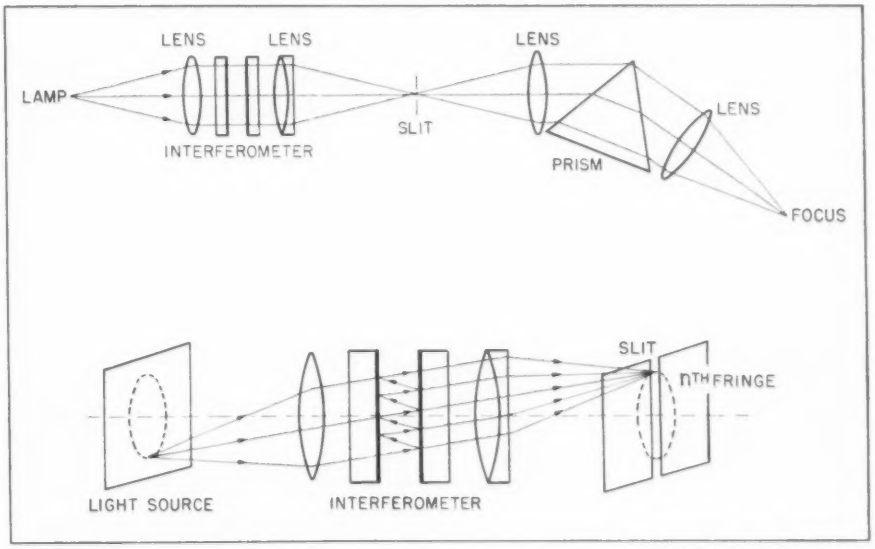
While the Army's program entails much pure research, the major portion of its effort is devoted to applying new processes and procedures to the practical aspects of modern warfare. On the other hand, while the Navy is devoting considerable time to the applied problems particular to naval operations, its efforts are being devoted more to pure research, leaving applications up to other agencies.

Ultimate Length Standard Chosen As Mercury 198 Radiation Wavelength

A NEW STANDARD OF LENGTH exists in the wavelength of green radiation of mercury 198, an isotope transmuted from gold by neutron bombardment. In precision, reproducibility and convenience the new standard is superior to both the standard meter and the red line of cadmium, according to recent investigations by Dr. William F. Meggers of the National Bureau of Standards. Preliminary measurements have shown an accuracy of one part in a hundred million of relative values and one part in a billion is theoretically possible.

Since 1889 the world's standard of length has been the "meter" distance between two lines on a platinum-iridium bar. Fundamental measurements throughout all of science and industry are based on this standard, but it has several disadvantages. First, line standards are unsuitable in certain fields of measurement. Second, the intrinsic nature of lines ruled on surfaces—such lines are in effect small furrows—limits the precision attainable. Third, the meter is not readily reproducible.

Because the standard meter does not afford sufficient precision in some fields, the red line of cadmium has been used for precise measurements. However, the cadmium standard also has serious disadvantages. First, there is a fine structure in the red radiation that prevents the line from being as sharp as desirable and limits the precision possible. Second, the cadmium standard requires excitation in a fur-



National Bureau of Standards

IN USING MERCURY ISOTOPE RADIATION to standardize units of length, a train of optical instruments for observing interference patterns is used. Setup consists of a radiation source, collected by a lens, which illuminates a Fabry-Perot interferometer. Waves between interferometer planes are found, without counting, from an approximate value, relative values of their wavelength, and measurements of their patterns.

nace, which entails unwanted broadening of the spectral line because of relatively high temperature.

The green line of mercury 198 has none of the disadvantages of either the meter or the red line of cadmium. The normal human eye is far more sensitive to green than to red; this is an important consideration, as the interferometer, with which lengths are measured and compared, is visually adjusted. All other characteristics desirable in a light wave standard—ability to be reproduced, absolute sharpness of wavelength, intensity of spectral line, life and convenience of maintenance—are possessed to a greater extent by this mercury isotope.

Plastic Edge Improves Aircraft Control Surfaces

GREATER IMPACT STRENGTH has been given the thin trailing edge of metal ailerons and elevators of DC-6 transports by substituting a glass cloth laminate for the aluminum alloy previously used, according to the Douglas Aircraft Company. The plastic-impregnated edge was developed by Douglas structural engineers to avoid minor damage caused by impact with ladders and stands used by maintenance and service crews during engine overhaul.

Not only does the new material tend to resist damage, but it lends itself to quicker repair. It consists of three plies of glass cloth impregnated with a fire-resistant polyester resin. Formed on steel dies, it is hardened under a heat process requiring 20 minutes. It is 0.030 in. thick.

ASME Honors C. E. Lucke For Professional Division Idea

THE IDEA of organizing an engineering society into units, or professional divisions, of the parent group, was originated 40 years ago by Charles Edward Lucke, now professor emeritus of mechanical engineering at Columbia University. His plan of "societies within a society" forms the framework of The American Society of Mechanical Engineers, which has grown to 24,000 members in 19 professional divisions, each group working in a special branch of engineering.

Because of his achievement, the ASME, during its recent annual meeting in Atlantic City paid Dr. Lucke a special tribute. At a meeting of the Council, he was presented with a scroll by the ASME Oil and Gas Power Division.

Arc Welding Design Awards

AWARD WINNERS in the arc welding Design-For-Progress Program have been announced by trustees of the James F. Lincoln Arc Welding Foundation. The first main award was divided among Paul F. Hackethal, Clarence C. Mast and Douglas W. Hamilton, all of the Koppers Co., Aeromatic Propeller Dept., for their paper on the design of a welded, variable pitch propeller hub for light planes.

The second main award went to Kiser E. Dumbauld, Bureau of Bridges of the Ohio State Highway Dept., for his paper on the redesign to welded construction of three Ohio bridges.

The third main award was received by G. J. Storatz, Heil Co., for a paper on the redesign to welded construction of a large piece of earth-moving machinery made by his company.

Savings to industry of two billion dollars are represented by arc welding designs illustrated in these, and the other 464 award papers, according to the secretary of the Foundation. Complete list of award winners is available from the James F. Lincoln Arc Welding Foundation, Cleveland.

American Weldment Manufacturers Association Organized

TO STANDARDIZE DESIGN AND MANUFACTURING PROCEDURE of weldments to be used as machine components the American Weldment Manufacturers Association, an organization of contract welding shop operators, was organized recently. A year of groundwork culminated in a two-day organization meeting, at which policies were set and officers elected.

Variation in cost and quality gave the original impetus to this organization. Without definite standards to guide them, welding shops often submit bids against one another with a wide variance in price. This makes it appear that at least one bidder does not know what he is doing or how much it actually costs to do a job of welded fabrication. However, the wide difference between the two prices may reflect the different manner in which the two organizations operate. The high price may include such extras as stress relieving, X-ray inspection, sand blasting and painting, while the low bid is merely for necessary labor and materials for fabrication.

Proper engineering for welded design is important to the success of a weldment, and the new organization will place emphasis on engineering services rendered by member companies. AWMA membership constitutes a seal of acceptance by the rest of the welding industry and should be a guide to potential purchasers of weldments.

FIRST PRESIDENT of the newly-organized American Weldment Manufacturers Association—K. W. Ode, Falk Corporation.

The association will attempt to achieve the following objectives:

1. Stimulate the growth and improvement of the weldment manufacturing industry from both the engineering and commercial standpoints.

2. Collect and disseminate to members statistics and information of value on such matters as capacities, facilities, improved processes, and personnel relations.

3. Promote the establishment and improvement of standardized weldment designs, specifications, manufacturing procedures and applications.

4. Promote among its members a spirit of voluntary cooperation for the improved production and increased application of machinery weldments; conduct technical, business and market research; and maintain a high standard of product.

Membership is not limited as to

the number of men from one company who may join. Each company, however, is limited to one vote. There are, according to the constitution, three classes of members: Company, Associate and Academic.

Company membership embraces contract welding shops engaged in the manufacture for sale of weldments which are to be used as component parts of machinery. Associate membership will include persons or companies associated with the manufacture of welding equipment or tools or persons or companies associated only with the manufacture of weldments as component parts of other products and not for sale. Academic membership is confined to individuals engaged in the teaching of welding and associated with accredited institutions of learning. The Associate and Academic membership classifications are not eligible to vote or hold administrative offices.

Officers elected at the organization meeting were:

K. F. Ode, Falk Corp., Milwaukee, Wis., president; W. C. Simpson, Lukenweld, Inc., Coatesville, Pa., vice-president; Hugh Hodges, Graver Tank and Manufacturing Co., Inc., East Chicago, Ind., secretary; A. S. Fredrickson, Lakeside Bridge and Steel Co., Milwaukee, treasurer. In addition to these officers, the association's board of directors includes:

Walter G. Koch, International Steel Corp., Evansville, Ind.; Louis T. Kenney, United Welding Co., Middletown, O.; Charles Stewart, A. C. Wood Co., Rockford, Ill.; Sylvester V. Williams, Struther Wells, Titusville, Pa.

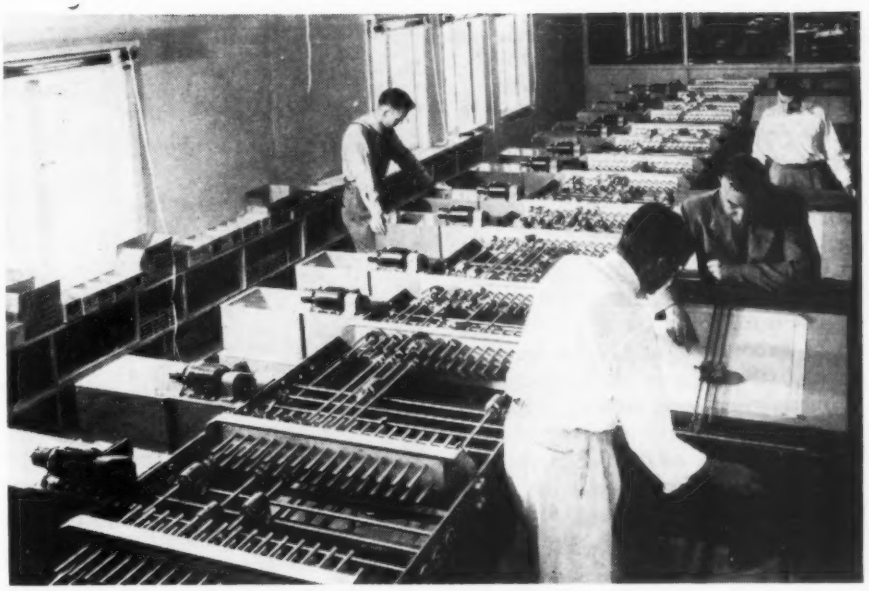
Atomic Energy Commission Industrial Advisory Group

TO SPEED UP INDUSTRIAL OPPORTUNITIES in the atomic energy field, the United States Atomic Energy Commission has announced the formation of a Board of Consultants to include industrial leaders in a number of business fields. James W. Parker, President and General Manager of the Detroit Edison Company is to be Chairman of the new group of consultants.

Among other industrial leaders invited to assist the Commission in accelerating business opportunities, including power, are: O. E. Buckley, President, Bell Telephone Laboratories, New York, N. Y.; Donald Carpenter, Vice President, Remington Arms Company, Bridgeport, Conn.; Dr. Gustav Egloff, Director of Research, Universal Oil Company, Chicago, Ill.; Paul Foote, Exec. Vice-President, Gulf Research and Development Company, Pittsburgh, Penna.; Robert G. Wilson, Chairman of the Board, Standard Oil Company of Indiana, Chicago, Ill.; and Col. Walker Cisler, Chief Engineer of Power Plant, the Detroit Edison Company, who will serve as Exec. Secretary to the consultant group. He is presently acting as consultant to the Commission.

Chairman David E. Lilienthal, stated that the Consulting Board had two initial purposes: First, to aid the Atomic Energy Commission in making rapid headway towards the earliest possible practical application of atomic energy by private business; and second, to place the consultants in a position, within security limitations, to keep American industry informed of developments in the Commission's widespread activities of research and development.

All members of the Consulting Board (to which additions will be made) will be cleared by the Commission for access to secret data necessary for their deliberations and rec-



DIFFERENTIAL ANALYZER recently installed at the University of California at Los Angeles receives complicated mathematical problem from members of the engineering staff. The machine, built and first to be commercially installed by the General Electric Company, will be used in the Institute of Numerical Analysis at the University, established to provide high-speed computing service and to do primary research in applied mathematics.

Institute of Numerical Analysis Established on West Coast

NEWEST UNIT of the National Bureau of Standards—the Institute of Numerical Analysis—is to be established at the University of California at Los Angeles, according to an announcement by Dr. Edward U. Condon, Director of the Bureau.

One of the high-speed electronic computing machines now under development by the Bureau of Standards will be installed at the Institute when completed. These computers will solve problems in minutes that now take days to work out, and will solve in days problems that are now out of the reach of scientists. Design specifications call for high memory capacity and automatically sequenced mathematical operations from start to finish at speeds attainable only with electronic equipment.

The machines can conceivably revolutionize the field of applied mathematics. Of particular importance both to the physical sciences and to technical industries will be the fact that the Institute will be able to set up a mathematical counterpart of an actual situation, which permits the situation then to be studied through relatively inexpensive calculating rather than costly experimentation. Great as has been the progress of the past century, the time has come when many problems of great importance, especially in hydrodynamics, aerodynamics, and meteorology, can only be handled by extremely rapid computers.

ommendations. Mr. Lilienthal said the industrial leaders would make a survey of the Commission's activities in the field of power development, including research work at Atomic Energy Commission's facilities. This includes the program for the new Knoll's Atomic Power Laboratory, now under construction at Schenectady, New York, to be operated for the Commission by General Electric, and the power studies now going on at Clinton National Laboratory, at Oak Ridge Tennessee, where more than a score of industrial and engineering firms are working on atomic power problems. The industrial advisory group will recommend to the Commission methods of expanding and intensifying industrial participation in the atomic energy project.

Radio Audience Reaction Recorded by Radar-Type Device

A NEW AUDIENCE MEASUREMENT DEVICE for monitoring radio broadcast reaction has resulted from application of wartime radar principles. This device will measure size of radio audiences and will provide broadcasters with tape-recorded reports showing trends for all listener segments—in big cities, small towns and farms, and at all income levels.

Conceived by Dr. Peter C. Goldmark, Director of Engineering Research and Development, Columbia Broadcasting System, the new device will use but one channel in the ultra-high frequency range.

A high frequency signal is broadcast in all directions from a radio station transmitter. Throughout the transmitter area, a cross-section of types of radio homes will be equipped with a device that will automatically and continuously report back to the transmitter while the sets are in operation.

Each report will contain the following information: When the set is in use; what station is tuned, minute-by-minute; income level of family, and location of radio set.

As reports return to transmitter, the information is recorded electronically and cumulatively, minute-by-minute, for each program on each station tuned by each set. A permanent record is made of program audience size for all stations and income groups into which listeners are divided.

The new technique has been named "Instantaneous Audience Measurement Service."

Largest Land Plane Flight Tested

WORLD'S LARGEST LAND PLANE—the XC-99 troop, cargo, and hospital transport built for the Air Force by Consolidated Vultee Aircraft Corporation—took to the air recently on its first test flight. The double-decked aircraft has six 3,000-hp pusher-type engines.

The new transport is a sister ship to the B-36, world's largest bomber. The Air Force has ordered 100 of these 10,000-mile bombers for its strategic fleet. Wingspan of the two planes is the same—230 feet. The XC-99, however, is 182½ feet long and 57½ high, 20 feet longer and 10 feet higher than the B-36.

The 265,000-pound experimental XC-99 can haul 400 fully equipped troops, or 100,000 pounds of cargo, or 300-odd litter patients and their attendants. The Air Force's largest personnel transports during the last war carried only 50 soldiers. The new global transport has a top speed of more than 300 mph and a maximum range, with reduced loads, of 8,100 miles. Service ceiling is 30,000 feet.

Chief wartime use of the XC-99 would be rapid transportation of soldiers and material in quantities heretofore considered impossible. It is, for example, the only airplane in existence that with slight modification could haul the largest components of a Ground Force division. Volume of fuselage is 30,000 cu ft, equal to volume of 10 railroad freight cars.

Design studies of the XC-99 as a long-range, low-fare, 204-passenger air-liner were completed but shelved, because of unavailability of gas turbine power plants suitable for commercial operation.

SAE Annual Meeting Stresses Application

ADVANTAGEOUS APPLICATION of wartime automotive engineering developments was the underlying theme of the 1948 Society of Automotive Engineers annual meeting and engineering display. Held last month in the Book-Cadillac Hotel, Detroit, Mich., a large portion of the society's 15,000 members attended sessions where 50 technical papers were presented and discussed.

Programs included engineering symposiums on problems of diesel engine smoking reversing propellers and requirements of modern fuels and lubricants. Discussions and papers put emphasis on utilization of modern automotive design, materials and production methods. Advancement was so rapid during wartime, that principles and methods used could not be completely investigated. Conference sessions saw the interchange of much valuable information learned by experience with these new ideas.

Low-alloy high tensile strength steels can afford economic advantages when used in motor vehicles, according to C. L. Altenburger, Great Lakes Steel Corp. Judicious use of this will enable fabrication of more products from existing steel tonnage. Along similar lines, W. E. Jominy, Chrysler Corp., said that the most expensive and least expensive automotive alloy steels can be given the same physical properties when properly heat-treated. However, from the standpoint of design, cheap alloys cannot always be substituted for expensive alloys because "the proper heat-treatment" is not always practicable. Jominy also indicated that for parts stressed in bending or torsion, it is good practice to specify not less than 90 percent martensite in the outer layer of any portion in the "as quenched" condition. This layer need not be deeper than one-quarter of the radius.

For parts stressed mainly in tension,

such as bolts, 90 percent martensite to the center is desired.

Careful pre-loading of bolts, according to W. C. Stewart, American Institute of Bolt, Nut and Rivet Manufacturers, is recommended to assure satisfactory performance. Pre-loading of bolts is also useful in structural applications where joints are generally loaded in a shearing direction.

Lacquers and synthetic enamels, currently used by the automotive industry, are undergoing improvements in manufacture, application and performance, according to M. G. Bell and W. W. Bauer, Pittsburgh Plate Glass Co. Attention is now directed to avoid corrosion on the underside of metal and in isolated locations.

Refractory porcelains may be used as material for turbine blades in turbojet power plants of the future. Despite short development period, reported by R. F. Geller, National Bureau of Standards, non-creeping porcelains can now replace metals at 1,500 F temperatures. It remains to be seen whether porcelain blades can resist thermal and mechanical shocks in turbine service, but in any event, another high temperature material is now available. At high temperatures, porcelain blades with tensile strength of 17,000 psi would be the equivalent of metal blades with 47,000 psi tensile strength. Net efficiency of turbine powerplants may be increased by using temperatures up to 1,800 F, as suggested by porcelain investigation.

Motor vehicle replacement was presented as a problem in economics rather than in technology by Prof. Joel Dean, Columbia University. As the age of a unit advances, maintenance cost increases, new models become available, and market price of the used unit reduces rapidly. These economic factors should be considered before each major overhaul.

Part-life-expectancy was described as a basis for preventive maintenance, repair, and replacement programs by W. J. Cumming, the White Motor Co. He studied vehicles with 90,000,000 miles of service over a ten year period and discovered the frequency of causes for vehicle delay. Electrical system troubles caused 30 percent of the total, engine troubles, 12 percent, and fuel system failures, 10 percent. These figures indicate how replacement of parts before they are worn out could save time, and also indicates where greatest design effort is needed.

Efforts of the U. S. Navy, world's largest owner and operator of diesel engines, to increase by four times the life expectancy of its power plants were outlined by W. G. Payne and W. F. Joachim, U. S. Naval Engineering Station. The principal task was stated to be one of reducing wear, in cylinder liners, from the present maximum rate of 0.005 in. to the average wear rate of 0.0008 in. per 1,000 hours of operation. Chromium plated cylinder liners have shown prolonged operating life, and some cast iron liners are showing satisfactory results. Fuel consumption, lubricating oil economy, lubricating oil temperature and cooling water temperature, all in influence cylinder wear according to these tests.

NEW PRESIDENT OF SAE—R. J. S. Pigott, chief engineer of Shell Development Co., was installed at the annual meeting of the Society of Automotive Engineers. Mr. Pigott started his career in the steam power field. Since then, he has been active in developments of gasoline, diesel and jet propulsion. He is the first petroleum technologist to be elected SAE president.

A Zero Was Lost

To the Editor:

We appreciate very much the fine publicity given our product by your excellent write up of the Articulated Fork Truck in the Product Design Section of the December issue.

We regret that an error was made regarding the capacity of the truck. This should have been 4,000 pounds, 54 in. long.

—M. W. McMillan
Baker Industrial Truck Div., The Baker-Raulang Co.

Ed.—Zero may be nothing by itself, but makes a whale of a difference when it gets away from its companions. We apologize for letting the printer get away with a zero.

MEETINGS

February 2–6
American Society of Heating and Ventilating Engineers—International Heating and Ventilation Exposition, Grand Central Palace, New York.

March 1–5
American Society of Mechanical Engineers — Spring Meeting. St. Charles Hotel, New Orleans, La.

March 3–5
Society of Automotive Engineers —Passenger Car and Production Division Meeting. Hotel Book-Cadillac, Detroit, Mich.

March 22–24
Chicago Technical Societies Council—Chicago Produtcion Show, Hotel Stevens, Chicago, Ill.

March 30–31
Society of Automotive Engineers —Transportation Division Meeting. Hotel Bellevue-Stratford, Philadelphia.

April 5–8
National Association of Corrosion Engineers—Annual Conference and Exhibition, Jefferson Hotel, St. Louis.

April 5–8
Southern Machinery and Metals Exposition—Annual Meeting and Exhibition, Atlanta Municipal Auditorium, Atlanta, Ga.

April 13–15
Society of Automotive Engineers —Aeronautic and Air Transport Division Meeting, Hotel New Yorker, New York, N. Y.

April 26–30
American Management Association Annual Conference and Packaging Exposition, Public Auditorium, Cleveland, Ohio.

May 3–7
American Foundrymen's Association Annual Meeting, Philadelphia, Pa.

May 20–21
Society of the Plastics Industry—Annual Meeting and Exposition. Hotel Ambassador, Atlantic City, N. J.

May 20–22
American Society of Mechanical Engineers—Oil and Gas Power Division Meeting, Hotel Jefferson, St. Louis, Mo.

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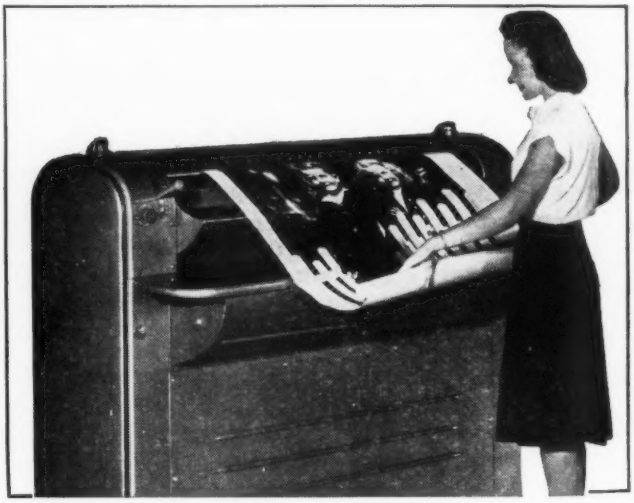

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International Harvester Co.
Lever Brothers
Montgomery Ward Co.
New York Central Railroad
Northern Pacific Railway Co.
Pan American Airways, Inc.
Paramount Pictures, Inc.
Parke, Davis & Co.
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E. R. Squibb & Son
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Ozalid in Canada—Hughes Owens Co., Ltd., Montreal

Charts for Calculating Root Stresses in Spur Gears

WAYNE H. BOOKMILLER
Gear Engineering Division, General Electric Company

THE LEWIS EQUATION is sometimes varied by using a factor to cover stress concentration and calculating the tooth form factor using the "worst application of load" method. The Lewis Equation, good for all pitches, is then expressed as follows; where

S = Root stress, psi
W_T = Tangential driving pressure, lb
P_D = Diametral pitch
K = Root stress concentration factor
Y = Tooth form factor
F = Face width, in.

$$S = \frac{W_T \times P_D \times K}{F \times Y} \qquad (1)$$

Stress concentrations in the root fillet make it advisable to include the factor K. T. J. Dolan and E. L. Broghamer, University of Ill. Experiment Station Bulletin No. 335, developed an empirical formula for K that can be applied to a wide range of gear tooth designs. The equation for a 20 deg pressure angle gear is; where

K = Stress factor
t = Tooth thickness at weakest section, in.
h = Height of parabola above weakest section, in.
b = Gear dedendum, in.
N = Number of teeth
r_t = Hob edge radius, in.
r_f = Minimum radius of fillet, in.

$$r_f = r_t + \frac{(b - r_t)^2}{\frac{N}{2 P_D} + (b - r_t)} \qquad (2)$$

$$K = 0.18 + \left(\frac{t}{r_f}\right)^{0.15} \left(\frac{t}{h}\right) \qquad (3)$$

A large number of scale layouts were made using the method illustrated in Fig. 1. Lay off a distance of one base pitch along the line of action from the start of involute action. Swing an arc to tooth surface to locate point of "worst application of load". The line through this point is tangent to the base circle. Values of K were calculated by Eqs 2 and 3.

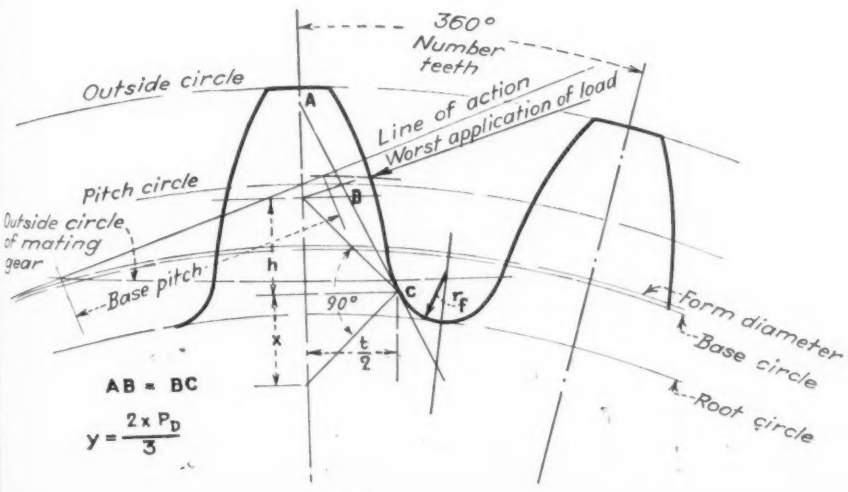

FIG. 1

Tooth deflection under load and the small chamfer usually put on the tip of gear teeth were not considered in making tooth layouts for Y and K. The contact ratio is somewhat reduced by the chamfer, but since the contact ratio is increased by tooth deflection, the use of the actual gear outside diameter is justified.

As an example of the use of Eq 1 and Figs. 2 and 3, consider the gear and pinion:

	Pinion	Gear
Number of teeth	28	85
Diametral pitch	20	20
Pressure angle	20 deg	20 deg
Pitch diameter	1.40 in.	4.250 in.
Addendum	0.050 in.	0.050 in.
Tooth thickness	0.077 in.	0.077 in.
Speed	20,000 rpm	6,600 rpm
Face width	$\frac{1}{2}$ in.	$\frac{1}{2}$ in.
Horsepower	15	

$$W_T = \frac{15 \times 33{,}000 \times 12 \times 2}{20{,}000 \times 2 \times 1.400} = 67.5 \text{ lb for opinion}$$

$Y = 0.695$ (Fig. 2) $K = 1.890$ (Fig. 3)

$$S = \frac{67.5 \times 20 \times 1.890}{0.500 \times 0.695} = 7{,}342 \text{ psi}$$

The use of Eq 1 and Figs. 2 and 3 will give accurate root fillet stresses of standard addendum spur gears cut to the data given. These curves have been used in designing spur gears for several years with good results, and are presented here as an aid to gear designers.

(continued on page 163)

ENGINEERS DRAFTSMEN EXECUTIVES

These informative books should be in your file

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Charts for Calculating Root Stresses in Spur Gears (continued)

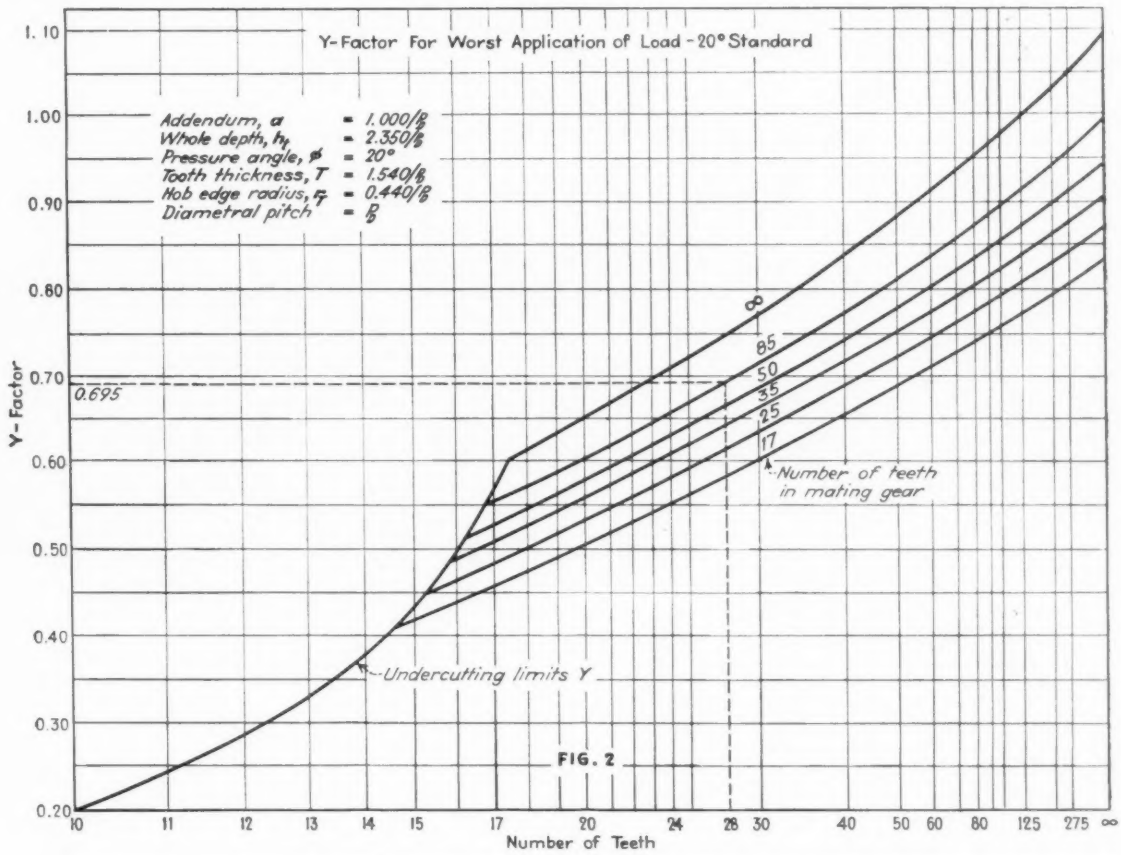

FIG. 2

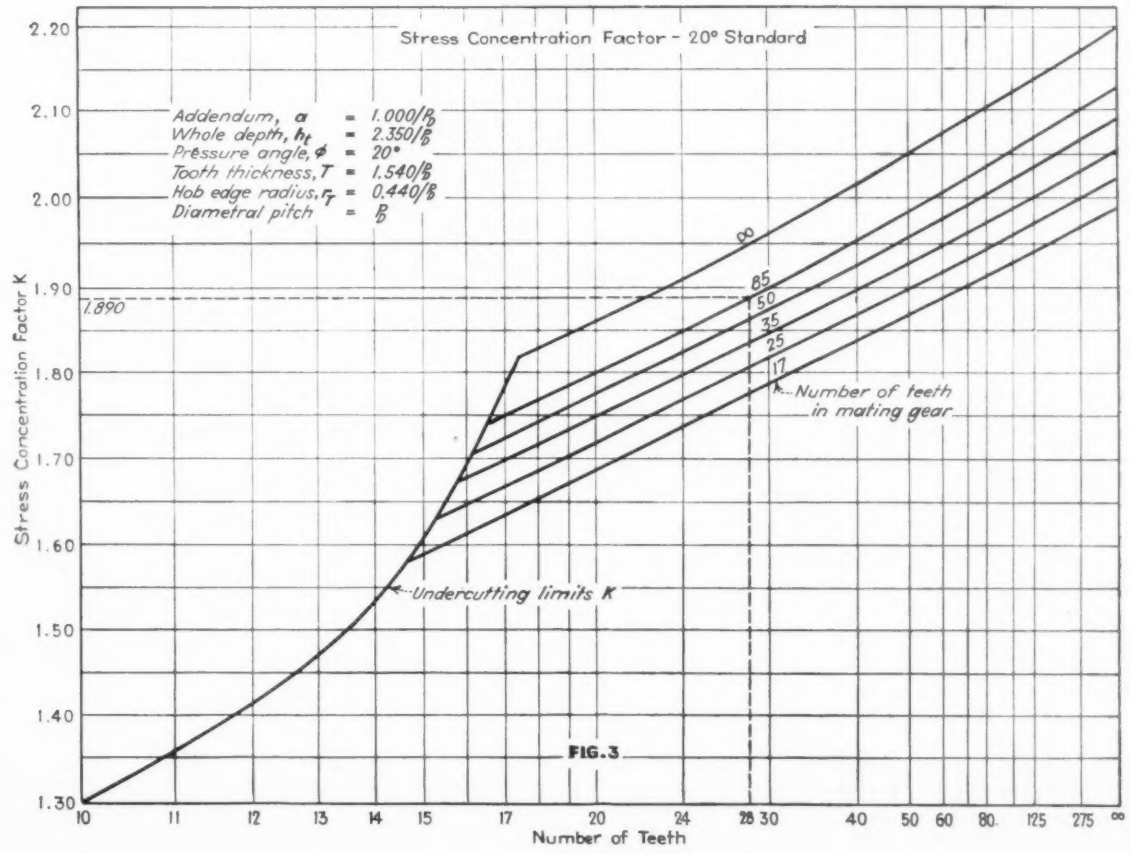

FIG. 3

ARMCO'S NEW "ELC" RESISTS CORROSION

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Now you can save money and avoid future service troubles by using the new ARMCO Stainless Steel Type 316 ELC (Extra Low Carbon) in welded processing equipment.

Annealing after welding is no longer necessary to prevent intergranular corrosion. Type 316 ELC staunchly resists corrosive attack near the welds when your equipment is in service. The reason is, this special ARMCO Stainless Steel has a *maximum carbon content of .03%*.

Heretofore, in some welded equipment, the excellent corrosion resistance of Type 316 has been safeguarded by the addition of columbium as a carbon-stabilizer.

Now the extremely low carbon content of ARMCO Type 316 ELC accomplishes the same purposes—*at less cost.*

This new grade is ideal for welded equipment exposed to corrosive conditions at temperatures below the sensitizing range. It can be used in equipment for the production of textiles, chemicals, pulp and paper, oil, and in other processing industries.

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NEW MATERIALS AND PARTS

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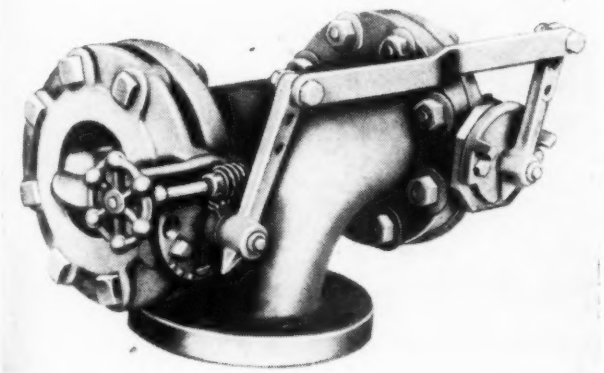
Permanent Valve Packing

United States Gasket Co., 610 N. 10th St., Camden, N. J.

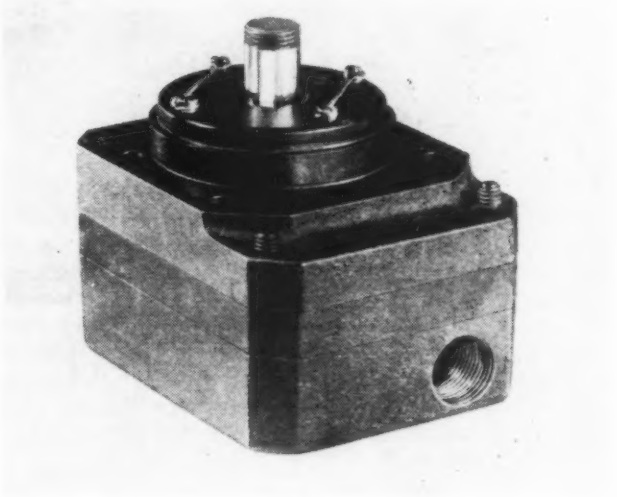
Chemiseal No. 510, a chemically inert, anti-adhesive and easily deformable valve packing, is now available. Fabricated from 100 percent unoriented teflon, the packing is inserted in valve stuffing boxes in the form of a sleeve or bushing. Minimum nut pressure is required to compress the material to the dimensions of the stuffing box. The characteristics of the material reduce binding of valve stems and reciprocating shafts and make replacements unnecessary. The packing is available in a wide range of diameters and lengths.



Three-Way Butterfly Valve

W. S. Rockwell Co., 200 Eliot St., Fairfield, Conn.

The Wafer three-way valve consists of two butterfly valves and a tee with the valves interlocked. The closing of one valve opens the other in any proportion. Actuation can be by hand wheel or lever and automatic operation can readily be applied. For large pipes, roller chain and sprocket connections are arranged. The unit is ideally suited for quick interchange, diversion of flow or mixing of gases or fluids. Sizes range from 4 to 60 in., American Standard Pipe Flange sizes, in cast iron or special alloys. Pressures up to 100 psi and temperatures to 1,800 F can be handled.



Hydraulic Gear Pumps

The Aro Equipment Corp., Bryan, Ohio

Three models of pilot-type flush-mounted hydraulic gear pump have been developed. Designed for continuous service at pressures up to 1,000 psi and for intermittent service up to 1,500 psi, these units are suitable for pressure lubrication and oil hydraulic applications. Materials handling, metal-working and earthmoving equipment are among the many uses. Of simple design, the pumps incorporate wear-resistant materials including nitralloy gears that move inside chrome plated faces of a cast iron housing. Operable directly or through a belt, gear or chain drive, the three pumps are rated as follows: Model 9,025—5½ gpm displacement at 2,800 rpm; Model 9,000—8 gpm at 1,800 rpm; Model 9,075—15 gmp at 1,200 revolutions per minute.

High-Density Alloy

General Electric Co., Pittsfield, Mass.

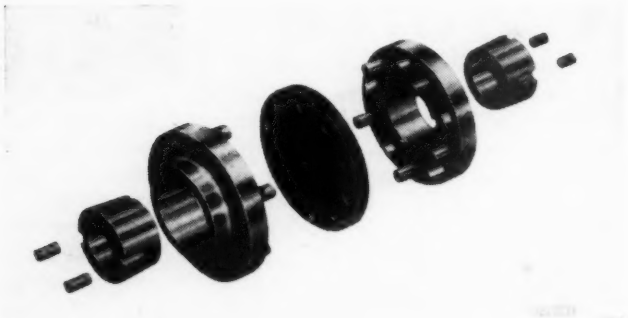
Hevimet is an alloy of tungsten, copper and nickel possessing a density 50 percent greater than lead. Originally developed for use on a gamma ray screen, the material is

adaptable to the construction of balance weights, centrifugal clutches, air screws and rotating parts in which maximum inertia and minimum size are primary design considerations. Combining a tensile strength of 85,000 to 118,000 psi with good machinability, the alloy is highly resistant to salt water corrosion, will easily plate with cadmium, chromium and nickel and can be silver soldered or brazed by standard methods. Hevimet is a sintered material made in non-porous sheets and blocks. Average density is 16.8 to 17.0 grams per cc and the Rockwell hardness is 30 to 40 "C" scale.

Pilotless High Vacuum Valve

Airmatic Valve Co., 1643 E. 40th St., Cleveland, Ohio

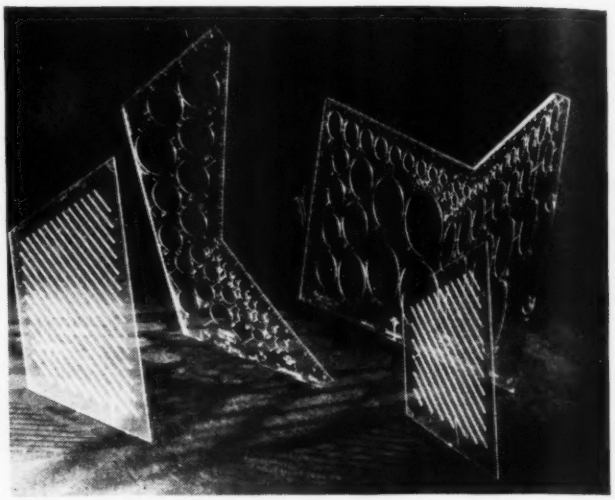
No pilot is required to actuate this solenoid high vacuum valve. Instant control is thus available for use in vacuum operated equipment and machine process applications. Of poppet design, the valve incorporates corrosive resistant internal parts. Resiliant synthetic rubber provides a positive seal without the use of packing. Laboratory and field test installations show average leakage to be only three microns. The valve operates from a 110 v d-c power source.



Flexible Coupling

Dodge Mfg. Corp., Mishawaka, Ind.

The Taper-Lock bushing used in this pin-type flexible coupling provides a firm positive grip on shafts and makes reboring unnecessary. The center disc is made of oak-tanned sole leather that affords flexibility, resiliency and strength. Removal of the disc is easily accomplished by loosening the coupling flanges and sliding them back on the shafts. The compact design occupies minimum space on the shaft and true running is insured by careful balancing of the whole assembly.



Isometric Drawing Stencils

Charvoz-Roos Corp., 1001 5th Ave., New York, N. Y.

Axonometric stencils offer the draftsman a quick method of presenting in one drawing a three-dimensional view of a complicated object. Fabricated from rigid sheets of Vinylite plastic, the instruments include isometric and dimetric stencils with many improved features. For example, the stencils have uniformly distributed extrusions on both sides so that they "float" above the surface of the drawing. The drafting edge is never in contact with the paper, thus providing a perfect inking edge and minimizing the danger of triangle smudges on the drawing. The dimensional stability of the material insures retention of the initial accuracy of the instruments.

Gridded Bearings

National Bearing Div., American Brake Shoe Co., St. Louis 10, Mo.

High load capacity and long life are claimed for these gridded lead-tin bronze-backed bearings. Grids are filled with babbitt and the bore is coated with a 0.002 in. lead-tin "run-in" surface. The centrifugally-cast bronze backing gives high thermal conductivity and conformability without fatigue. Babbitted grids make the bearings "self-healing" and provide a safety factor that protects shafts. The 0.002 in. "run-in" surface increases resistance to seizure and corrosion. Applications are in heavily loaded Diesel engines and similar heavy-duty services as main and connecting rod bearings. Loads of over 3,500 psi projected area can be carried with

POWDER METALLURGY

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Low Cost, Self-Oiling, Long Life

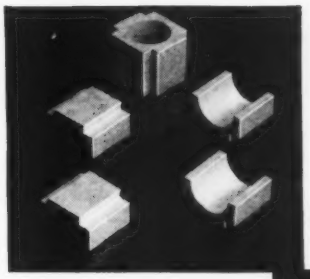
SLEEVE BEARINGS

MANUFACTURERS of many types of equipment can gain these advantages by using Johnson LEDALOYL Bronze for bearings and small parts. LEDALOYL is a product of powder metallurgy, manufactured by an exclusive process using pre-cast, pre-alloyed bearing bronze.

LEDALOYL bearings and parts are molded, under pressure, to required shape and size, thus eliminating expensive machining operations. When quantities of any size are used, the unit cost is surprisingly low.

Another valuable feature is the self-lubricating action of LEDALOYL. Myriads of tiny, evenly spaced pores serve as miniature oil wells. When the bearing is in use the oil is metered to the shaft . . . when at rest the oil is absorbed by these pores. This action provides adequate lubrication at all times . . . preventing wear and in most cases eliminating the expense and bulk of other lubricating aids. Service records show long, trouble-free operation on many types of installations.

When you are looking for ways to reduce cost and to increase efficiency in your bearing applications . . . call on Johnson Bronze. We manufacture all types of Sleeve Bearings . . . we are ready to serve you now.

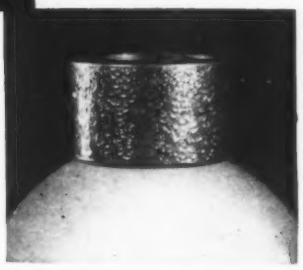


Low Cost

Odd shaped parts and self-aligning bearings when produced by conventional methods require considerable machine work, as compared with one forming operation in LEDALOYL.

Self-Oiling

Place a LEDALOYL bearing on a lighted lamp bulb. Watch the oil sweat from the pores. Remove the bearing and the oil is reabsorbed. This illustrates the self-lubricating and oil retaining action.



Long Life

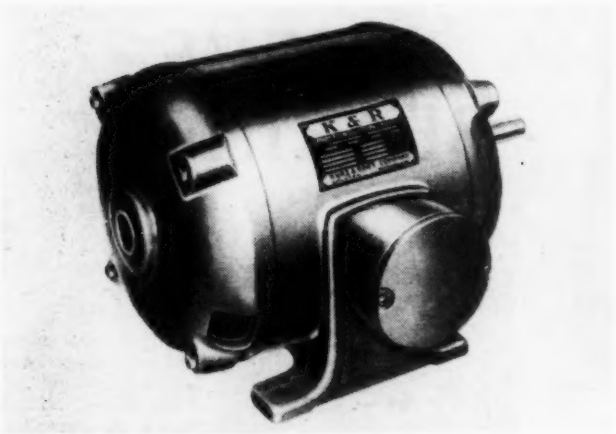
On a recent "break-down" test, LEDALOYL Bearings operated week after week on a schedule of nine hours a day for five days a week. The accumulated hours of test run represented a normal use of about five years, yet there was no sign of wear in the bearings or on the shaft.

JOHNSON BRONZE
SLEEVE BEARING HEADQUARTERS

BRANCHES IN 20 INDUSTRIAL CENTERS

JOHNSON BRONZE COMPANY • 508 South Mill Street . . . New Castle, Pa.

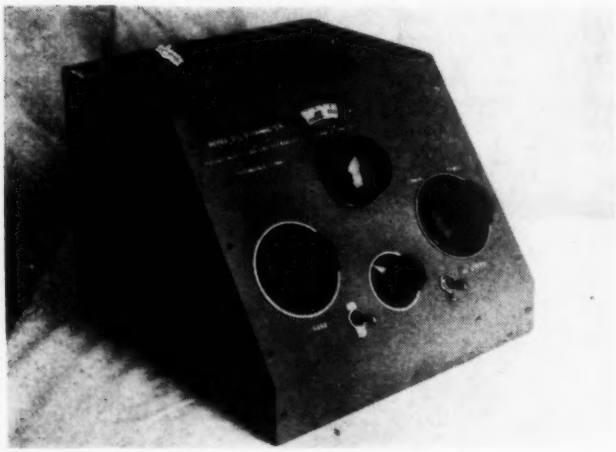
shafts as low as 160 Brinell hardness. Minimum depth of grids is 0.008 in. and minimum area of babbitt is 40 percent. Customarily made as half bushings, these bearings can be furnished as full cylindrical units.



Dripproof Induction Motors

Kurz & Root Co., Appleton, Wisc.

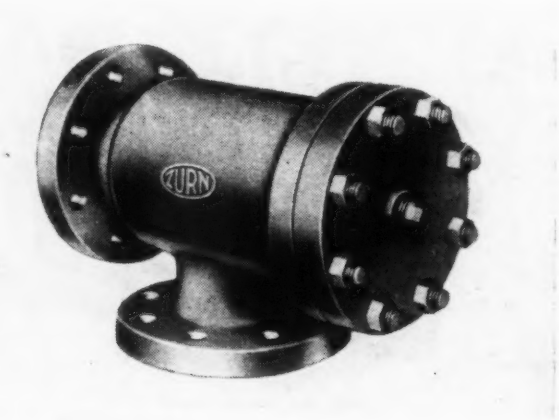
A line of dripproof three-phase squirrel cage induction motors is available with two speed ratings in the 1-5 hp range. All motors have prelubricated sealed ball bearings and pressure cast rotors with aluminum bars and integrally cast fan blades. Built to NEMA performance and dimensional standards, these motors operate on 220/440 v at 60 cycles with a 40 C temperature rating or at 50 cycles with a 50 C continuous duty rating. Models in the 1,750 rpm series are rated at 1, 1.5, 2, 3 and 5 hp; 1,150 rpm units give up to 2 horsepower.



Strain Gage Instrument

Anderson-Fluke Engineering Co., Springdale, Conn.

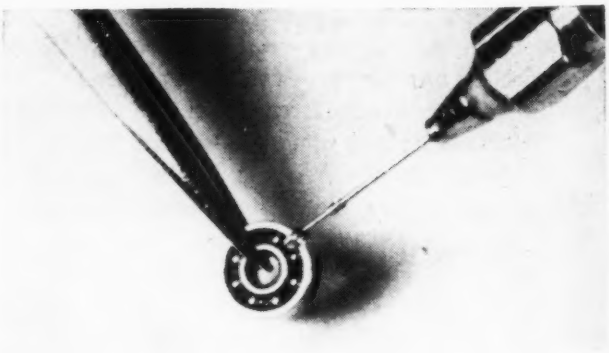
Twenty-four wire resistance type strain gages can be handled by the Model 301 direct reading Strainmeter. Separate zero-load gage readings are dispensed with by built-in zero-load bridge balancers. Gages of resistance from a few ohms to several thousand ohms can be used, provided the compensator gage is matched within three ohms. The dial is divided into 10 microinches per in. graduations and strains of 2 microinches per in. can be detected. For strains exceeding the range of the dial, a range extender switch is provided. Maximum strain range is 0.012 in. per in. Rapid selection of the gage to be measured is made on the 24-point switch at the left on the panel. The instrument weighs 11½ lb and measures 8 x 10 x 12 in. Accessories required are 1½ to 3 v dry cell battery and a galvanometer having 20 to 200 ohms internal resistance, 100 to 600 ohms external resistance with 0.05—0.01 microamp per mm sensitivity.



Angle-Type Strainer

J. A. Zurn Mfg. Co., Everett and Pittsburgh Aves, Erie, Pa.

The angle construction of this strainer permits installation directly on the pump or unit it is to protect. Space and fittings can also be saved by installing the strainer in a pipe line where it can serve as or replace a right angle connection. Various types are made with pressure ratings of 125, 150, 250 and 300 pounds. The latter type is particularly suitable for vapor, steam and gas pressure service. To provide for corrosion resistance and special flow characteristics, strainer-basket material and perforations are furnished to specifications. The body and cover assemblies are available in cast steel, semi-steel or bronze, depending upon the pressure requirement.



Miniature Ball Bearing

New Hampshire Ball Bearings, Inc., Peterborough, N. H.

Measuring ¼ in. OD $\frac{5}{64}$ in. bore x $\frac{3}{32}$ in. wide, the Micro miniature ball bearing is non-magnetic and non-corrosive. The bearing was developed for electrical, electronic, geophysical and similar applications requiring freedom from magnetic influences, as well as for general use where the

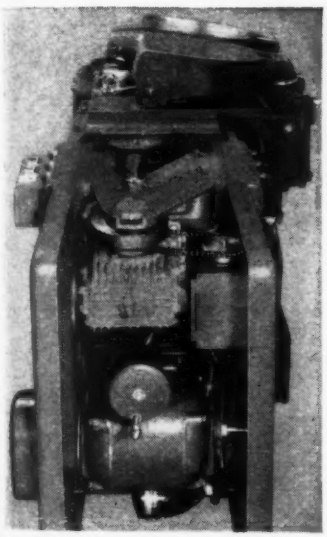
SMALLER GEARS do NOT mean SHORTER LIFE

Not when you are using Cone-Drive gearing for the job. For Cone-Drive gearing with its larger contact per tooth and MORE TEETH IN CONTACT gives you vastly lower inherent unit pressures . . . i.e., greater load capacity with smaller gears.

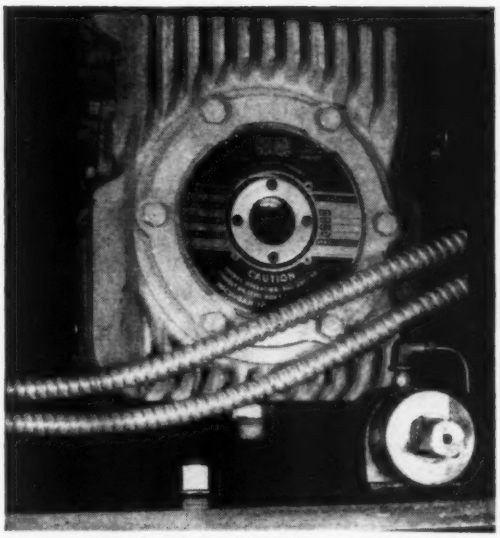
And here's a real design short-cut: Where possible, use a *standard* Cone-Drive speed reducer. You'll be surprised in how small a space it will fit and how much money it will save.

Ask for Bulletin No. 8901a

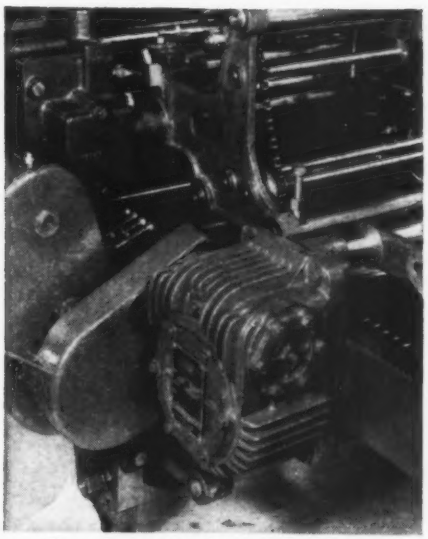
CONE-DRIVE DIVISION
MICHIGAN TOOL COMPANY
7171 E. McNichols Road • Detroit 12, U. S. A.



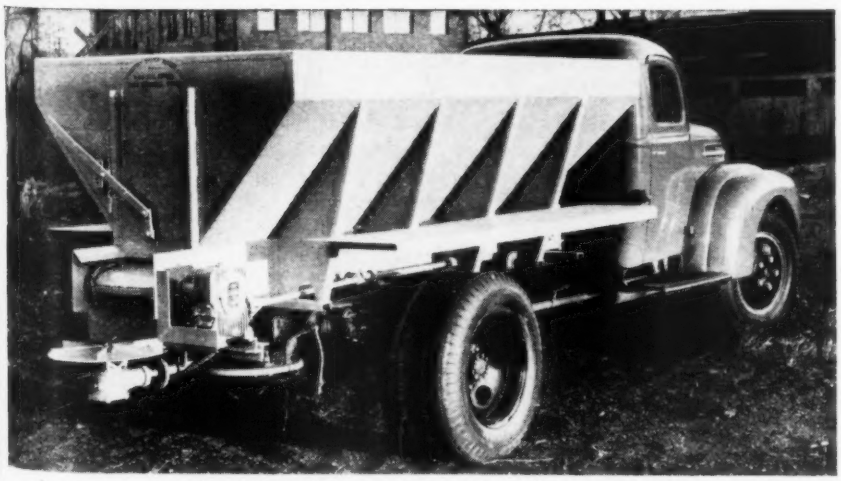
With this compact *standard* Cone-Drive speed reducer, Progressive Welder, in its flash welders, got "longer life, lower inertia forces, freedom from backlash despite higher loads . . ."



In the Michigan "870" gear finisher, the smoother slide movement drive—key to the 870's new higher standards of accuracy and versatility—is through a *standard* Cone-Drive reducer, compact and light enough to go in the machine head.



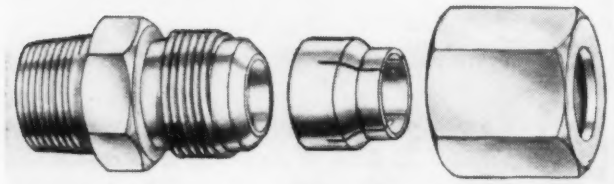
Here is a paper box machinery manufacturer who found it a lot less costly to use a *standard* Cone-Drive reducer in place of former gear-change boxes in his machines—and got increased load carrying capacity with longer life.



A compact *standard* Cone-Drive reducer drives the conveyor on several new lime-spreader trucks, such as this one by Weston Dump Body—a tough job when running with full loads over rough fields.

Most Cone-Drive *standard* reducers can also be water or fan-cooled—in which case you can just forget about thermal ratings.

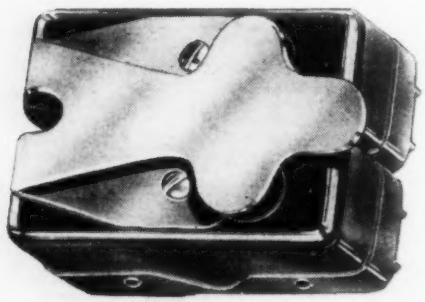
non-corrosive properties are desirable. Material is beryllium-copper (tensile strength 200,000 psi) hardened to about 42 Rockwell "C" scale. Assemblies are offered in both Class 1 and Class 5 precision tolerances and are of full-race design for maximum capacity.



Hydraulic Tube Fittings

Flodar Corp., 331 *Frankfort Ave., Cleveland, Ohio*

High resistance to extreme fluid pressures and heavy vibrations is reported to be the distinguishing characteristic of Grip Tube hydraulic fittings. In addition to the standard connector body and coupling nut, a separate contractable sleeve is used to seal the fitting on the tube. This hardened alloy spring-steel sleeve grips the flared tube with slotted fingers when the nut is tightened. Straight, union, elbow, side tee, tube tee and cross types, both male and female, are available. Sizes run from $\frac{1}{4}$ to $1\frac{1}{2}$ inches.



Snap-Action Switch

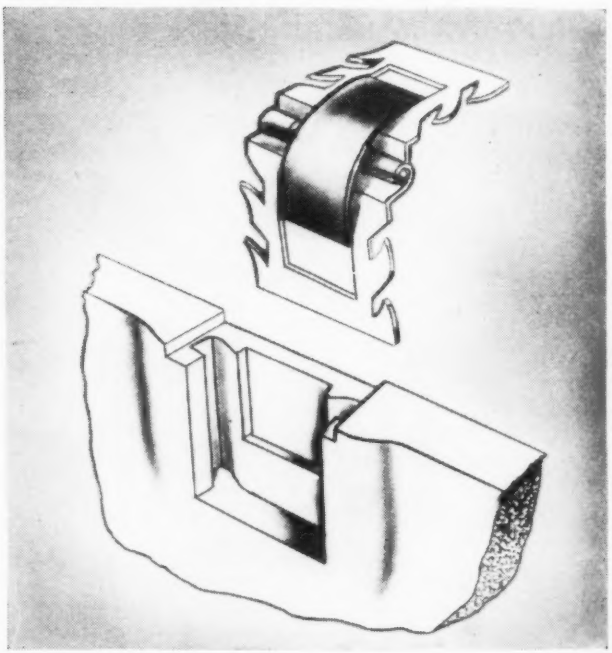
Unimax Switch Corp., 460 *W. 34th St., New York* 1, *N. Y.*

Circuit control with double-pole, double- or single-throw switching is provided by the Type SA-1 snap-action precision switch. Comprising an assembly of two standard Unimax precision switches ganged for mounting on one-inch centers, the switch is equipped with a duplex Adaptaplate that actuates both switching elements simultaneously. The plate is made of beryllium-copper and its construction affords the requisite transverse stiffness to assure uniform transmission of the actuating force to the operating pins of the two elements. Body dimensions are: $2\frac{1}{8}$ in. over-all length, $1\frac{3}{8}$ in. width $\frac{15}{16}$ in. height including Adaptaplate. The switch carries the ratings of 15 amp at 125 volts.

One-Step Metal Finish

Acryvin Corp. of America, Astoria, L. I., N. Y.

No chemical or mechanical surface pre-treatments or primers are needed when metals are finished with Acraclad. Both ferrous and non-ferrous metals can be coated in a single application once the surface has been thoroughly cleaned according to standard practices. The coating is non-toxic and highly resistant to corrosion by acids, oils, alkalies and salt spray. Baking time for each application is normally 10 min at temperatures ranging from 250 F to 350 F, although certain alloys require a maximum of 20 minutes. Application is by spray, brush, dip or roller coat, giving coverage of 350-450 square feet per gallon.



Snap-Action Hinge

General Electric Co., Plastics Div., Pittsfield, Mass.

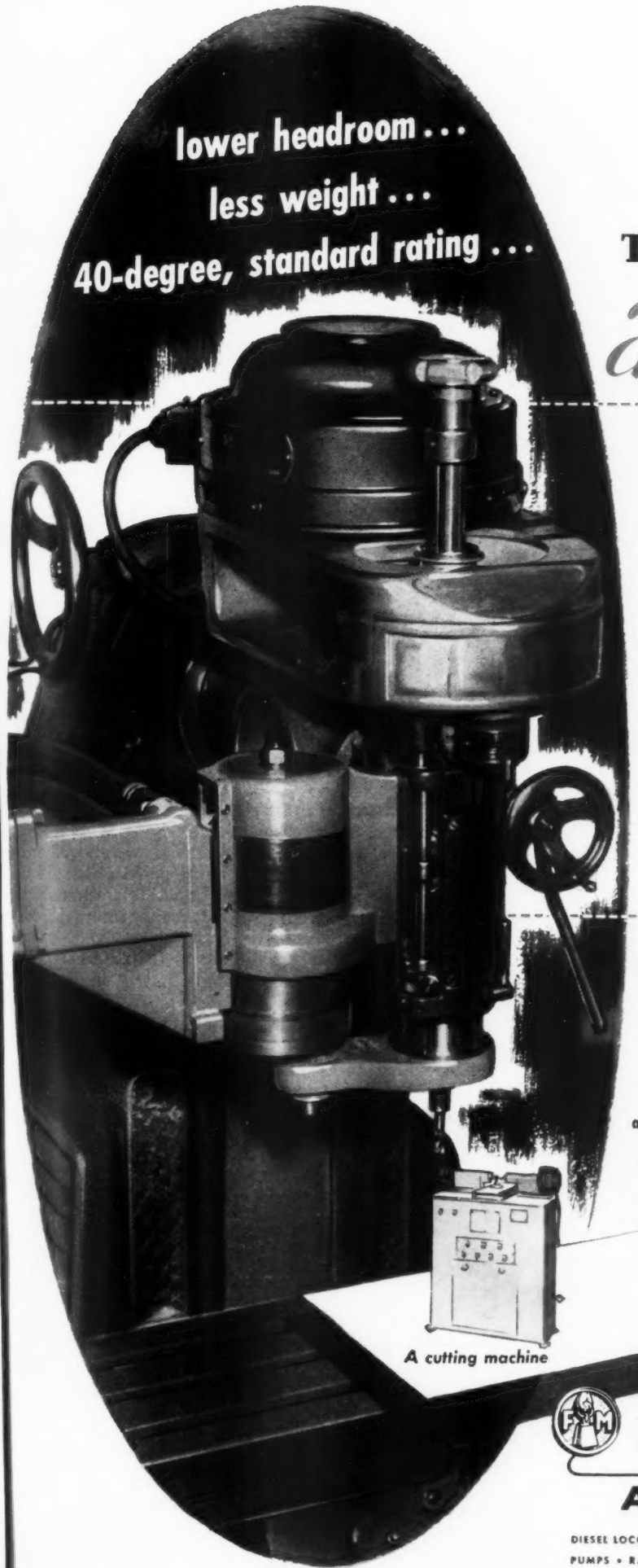
Manufacturing costs and assembly time are reduced through the use of this snap-action steel hinge that requires no screws or rivets for attachment to plastic containers. The hinge can be used on both thermosetting and thermoplastic materials, either with or without the spring clip. Attachment is made by teeth that bite into slots molded in the container material. A strong assembly is thus provided as the spring tension is concentrated on the metal rather than on the container material.

Refractory Coating

Whitman Co., 1407 *Esperanza St., Los Angeles* 23, *Calif.*

A refractory coating called Vitroseal is available for preventing spalling action, resisting heat penetration and decreasing carbon slag and clinker adherence in fire boxes, furnaces and crucibles. The material forms a semi-glazed protective monolithic wall of extreme hardness between fire and fire brick. The destructive effects of flame impingement and abrasion at temperatures up to 3,390 F can be withstood. The glazed surface speeds heat-up time

lower headroom . . .
less weight . . .
40-degree, standard rating . . .



THE FAIRBANKS-MORSE

axial air-gap

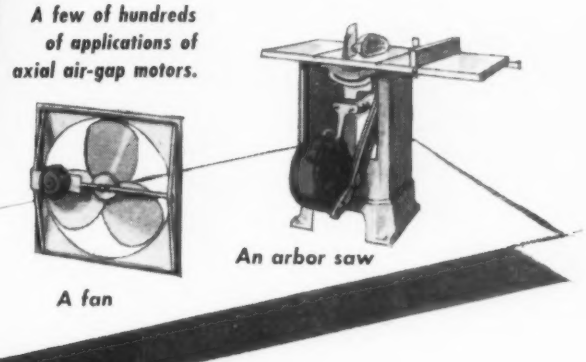
MOTOR

Most of the advantages of the new Fairbanks-Morse Axial Air-Gap motor are immediately apparent. Whether you're making or using drills, presses, pumping units—any of a wide variety of motor-driven machines—the benefits of a fully rated, 40-degree motor that is 50% shorter, 30% lighter than other motors, are obvious—*and important!*

Remember, too, that along with the novel advantages brought to you with this new line of motors—the ability to blend with the contour of your machine, the compactness, and wide adaptability—you continue to get the quality that has been manifested in Fairbanks-Morse electrical machinery for many years.

What the Axial Air-Gap motor does for this vertical drill it might well do for your machines: Greater eye appeal, more "buy" appeal, fine high quality performance.

A few of hundreds of applications of axial air-gap motors.



A cutting machine

A fan

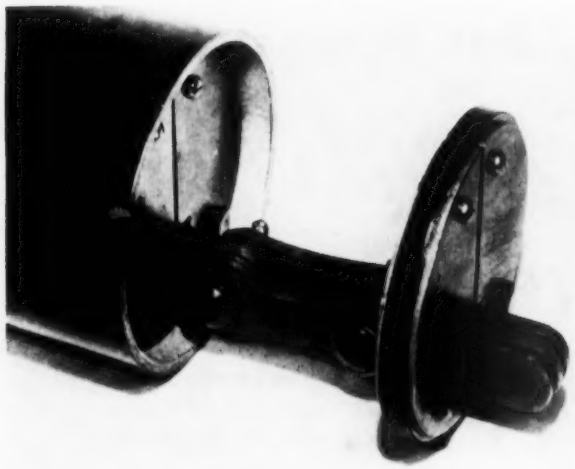
An arbor saw

FAIRBANKS-MORSE

A name worth remembering

DIESEL LOCOMOTIVES • DIESEL ENGINES • STOKERS • SCALES • MOTORS • GENERATORS
PUMPS • RAILROAD MOTOR CARS and STANDPIPES • FARM EQUIPMENT • MAGNETOS

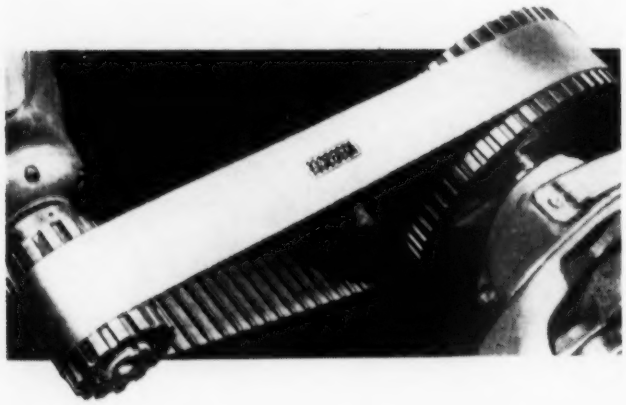
due to reflection and decreases heat loss through joints. Applications of a water solution of the powder can be made by brush or spray.



Flight Conveyors

Hopman Conveyors, Inc., Detroit 21, Mich.

Circular synthetic rubber flights mounted on sealed-pin chains are available for conveying a wide variety of materials through pipes or semi-circular trough sections. Inherently clean in operation, the flights are flexible and will follow a pipe in any direction. Applications include the conveying of materials such as coal, welding flux, abrasives, cement, sugar, cocoa, copper shot and flour. Flight sizes currently available will fit pipes and troughs having 3, 4, 6, 8 and 10 inch inside diameters.



Timing Belts

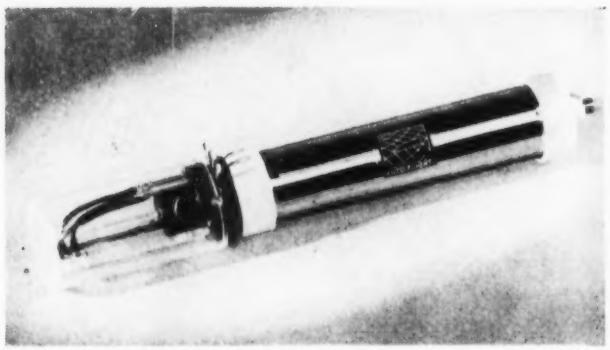
L. H. Gilmer Div., United States Rubber Co., Rockefeller Center, N. Y.

Steel cables embedded in oil-resisting synthetic rubber reduce stretch and make the use of slack take-up devices unnecessary. The rubber teeth which require special grooved pulleys minimize noise and slippage and provide positive engagement at belt speeds up to 10,000 feet per minute. Ideal for power transmission and synchronization purposes, these flexible belts are applicable to a wide variety of uses in the automotive, aviation, machine tool, business and industrial fields.

Flexible Tubing

Periflex Sales Co., 7200 Powers Lane, Philadelphia 42, Pa.

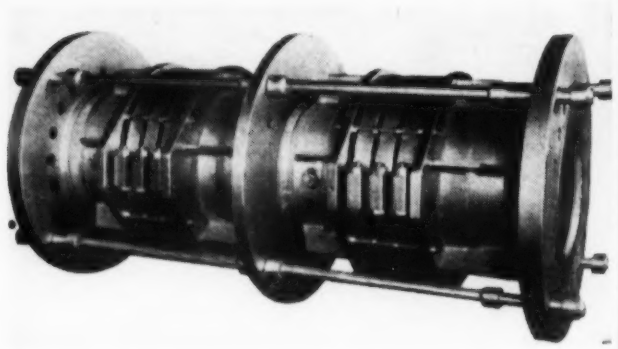
Ronaflex braid-covered rubber tubing will withstand liquid and gas pressures of 980 psi. Highly flexible and resistant to abrasion, the tubing is available with snap-on couplings for quick installation. The rubber is synthetic and the braiding is galvanized or stainless steel, aluminum or bronze. Ronaflex assemblies are suitable for use as engine fuel and oil lines, machine tool coolant lines, butane-propane gas lines, paint sprayer air lines, portable gas heaters and household appliances.



Linear Accelerometer

Autoflight Instruments Div., G. M. Giannini & Co., Inc., 285 W. Colorado St., Pasadena 1, Calif.

Linear output signals in varying ranges up to ± 25 G can be transmitted by this accelerometer. It is insensitive to quadrative accelerations and mass weight is magnetically damped so that optimum performance is obtained regardless of temperature or altitude. Signals are picked up on a recording milliammeter. Internal resistances of the instrument range from 100 to 20,000 ohms and either a-c or d-c can be used as the external power source. Dimensions are $6\frac{7}{8}$ in. long and $1\frac{1}{8}$ in. diameter. Weight is 6 oz. including mounting brackets. A modification of this instrument is a Maximum Indicating Accelerometer that can be expelled from aircraft or missile, recovered, read, reset and reused.



Universal Expansion Joints

Zallea Brothers & Johnson, 888 Locust St., Wilmington, Del.

Axial, lateral and/or angular movements of high temperature conduits can be absorbed by these universal expansion joints. Assemblies can be made to fit any

At your finger tips...

Piping Equipment for Every Design

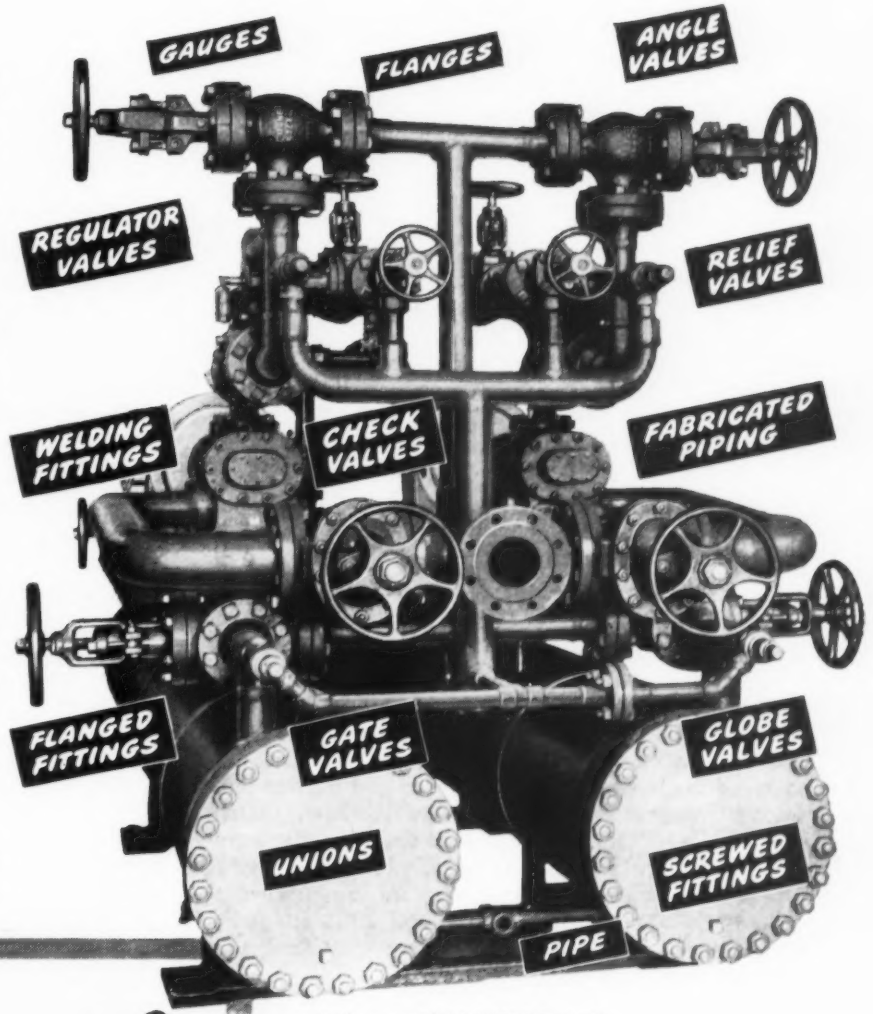
No hunting . . . no time lost . . . when you specify piping equipment from the Crane Catalog. It's organized for quick, easy reference. A truly complete selection is yours . . . the world's largest . . . of valves, fittings, piping accessories, and pipe for every design requirement.

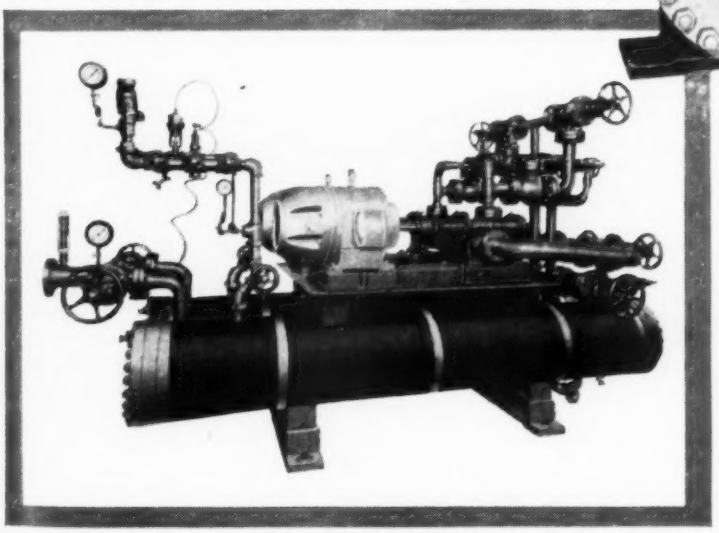
No compromise is necessary whether you're specifying for a simple lubricating line or a complex hydraulic system, for example. Crane offers all types and sizes of piping equipment . . . in brass, iron, and steel. Here's an opportunity to standardize without limitation.

ONE SOURCE OF SUPPLY
ONE RESPONSIBILITY
ONE STANDARD OF QUALITY

Product designer . . . builder . . . and machinery buyer . . . all benefit by the 3-way advantage of standardizing on Crane equipment. As it speeds designing, it simplifies your factory procedures. Your customers get the greater value that Crane equipment has been giving for more than 90 years.

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Ill. *Branches and Wholesalers in All Industrial Areas.*





(Above and left) ENCO fuel-oil pump set by The Engineer Company, designed with Crane piping materials.

(Right) **IN STEEL VALVES,** *Crane supplies gate, globe, angle and check patterns, in cast and forged materials, in pressure classes for all applications. Also, in a wide selection of corrosion-resistant materials, including bar stock valves. See your Crane Catalog or call your Crane Representative for complete specifications.*

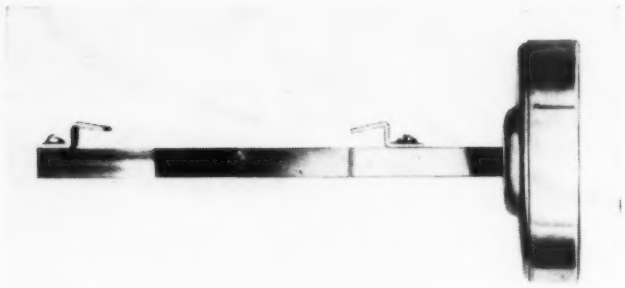
EVERYTHING FROM . . .

VALVES • FITTINGS
PIPE • PLUMBING
AND HEATING

CRANE

FOR EVERY PIPING SYSTEM

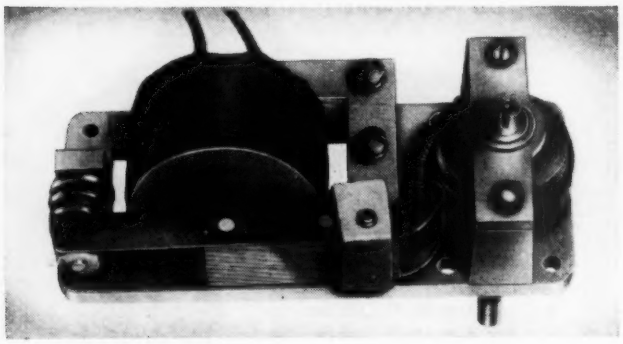
requirements by combining different types and sizes of the two corrugated elements and the interposed section of pipe. The expansion elements can be either of non-equalizing type for pressures up to 30 lb or self-equalizing for higher pressures. The length of the pipe section determines the amount of lateral movement. These joints are well suited for use in refineries, power plants and chemical process plants because the joint has no sharp crevices in which catalysts can pack.



Flat-Stem Thermometer

W. C. Dillon & Co., Inc., 5410 *W. Harrison St., Chicago* 44, *Ill.*

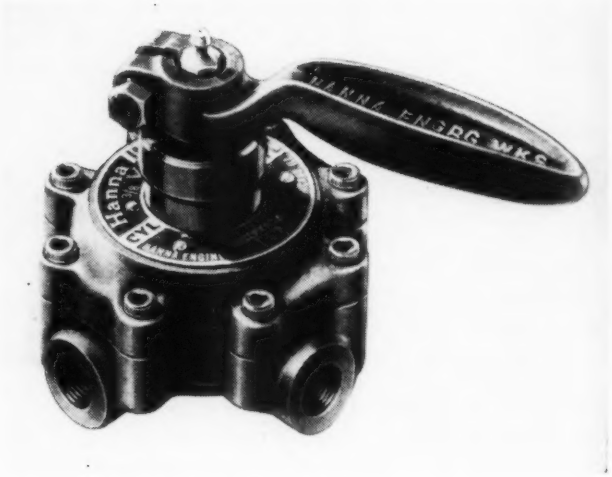
Designed for attachment to flat or rectangular surfaces, this flat-stem dial-type thermometer has many uses where the round-stem type is extremely difficult to apply. The heating element goes down snugly against the object under test and provides a wide heat absorbing area. The unit can be clamped in place or drilled and tapped and screwed into position. Applications include power bus-bars, switch blades, engine blocks and water jackets. The flat stem can be supplied in varying widths, thicknesses and lengths and in a wide range of metals. Standard capacities are: 0—200 F, 50—500 F, 150—750 F and 200—1,000 F; dials are either 3 in. or 5 in. in diameter; and Centigrade ranges are available on order.



Vibrator Type Motor

Piqua Machine and Mfg. Co., Piqua, Ohio.

Vibratrol incorporates a design different from the conventional type used in small electric motors. Compact and light in weight, this vibrator type motor combines all the advantages of the induction motor with the most desirable performance characteristics of the series motor. It has high starting torque, high overload capacity and good speed regulation. No radio interference is created as there are no brushes or contacts to spark. The unit is built for use on 115 v, 60 cycle, a-c lines.



Air and Hydraulic Valves

Hanna Engineering Works, 1765 *Elston Ave., Chicago* 22, *Ill.*

Unitite valves for air and hydraulic lines have been redesigned to incorporate a protective seal. Made in the form of a skirt, the neoprene seal is mounted on the valve stem underneath the handle to snugly shroud the boss on the bonnet. The lubrication fitting has been relocated in the end of the stem so that the valve disk and stem are pressure lubricated radially outward. Lubrication is therefore accomplished without taking the valve out of service or shutting off the flow. Body and bonnet design does away with knuckle barking.

Radiation Decade Scaler

Potter Instrument Co., Inc., 136-56 *Roosevelt Ave., Flushing, N. Y.*

Designed specifically for radioactivity measurements, the Model 2092 Decade Scaler is a completely self-contained instrument. Three plug-in type counter decades are used to provide a convenient decimal scale registration of each count. A switch is provided for the selection of a scale of 10, 100 or 1,000 in driving the mechanical register located on the front panel. The unit will resolve two pulses that are 5 microseconds apart and will count continuously with absolute accuracy at rates up to 130,000 counts per second. The pulse height selector is set at 0.25 volt sensitivity. Adjustable from 600 to 1,500 volts, a high voltage regulated power supply is included for the

Draw your own Conclusions!

Check the Coupon and Check the Facts!

✓ **SEE** *how Hi-Density assures uniform opacity.* Only VAN DYKE gives you HI-DENSITY lines that are uniformly opaque in drawings...and sharply white in prints.

✓ **NOTE** *the crisp, sharp prints.* Because you get blackness without thickness of lead deposit, there's a minimum of smudging and freedom from erasure-ghosts.

✓ **FEEL** *how smoothly VAN DYKE glides.* That's because VAN DYKE Microtomic Leads are made of pure crystalline graphite flakes – chemically reduced 100 times finer than is possible by old grinding methods.

✓ **TEST** *the stronger lead for longer wear.* A thermostatically controlled heat treatment produces extraordinary strength through the entire lead.

✓ **COMPARE** *the precision of grading.* Ninety-nine years of fine pencil making experience and the use of exacting formulae are your assurance of uniformity of lead in every degree.

MICROTOMIC

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HI-DENSITY

DRAWING PENCIL

ROUND LEAD in 18 degrees from Sketch-Pad 7B Soft to Naval Architects' 9H Extremely Hard.

EXCLUSIVE CHISEL POINT – a rectangular lead that gives you 20% more line-production between sharpenings! Six degrees only – 4B, 2B, HB, 2H, 4H & 6H.

TRADE MARKS REG. U.S. PAT. OFF.

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Dept. PE-2, 37 Greenpoint Ave., Brooklyn 22, N.Y.

Yes, I'll be glad to try a Microtomic VAN DYKE.

Send me FREE a _____ (degree) regular lead or a _____ (degree) Chisel Point.

Name_____

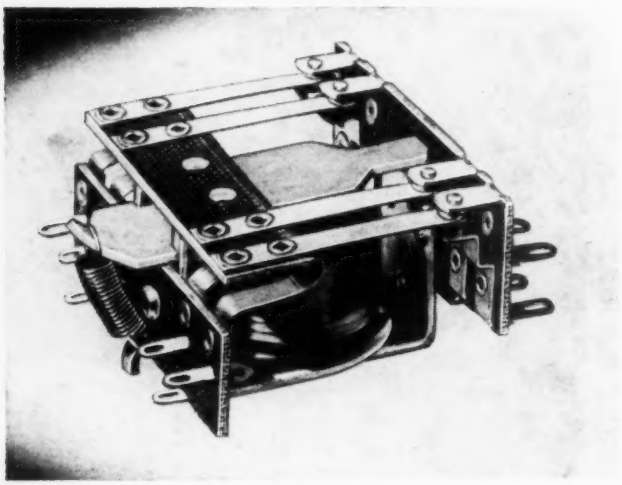
Firm_____

Street & No._____

City & State_____

Dealers Name_____

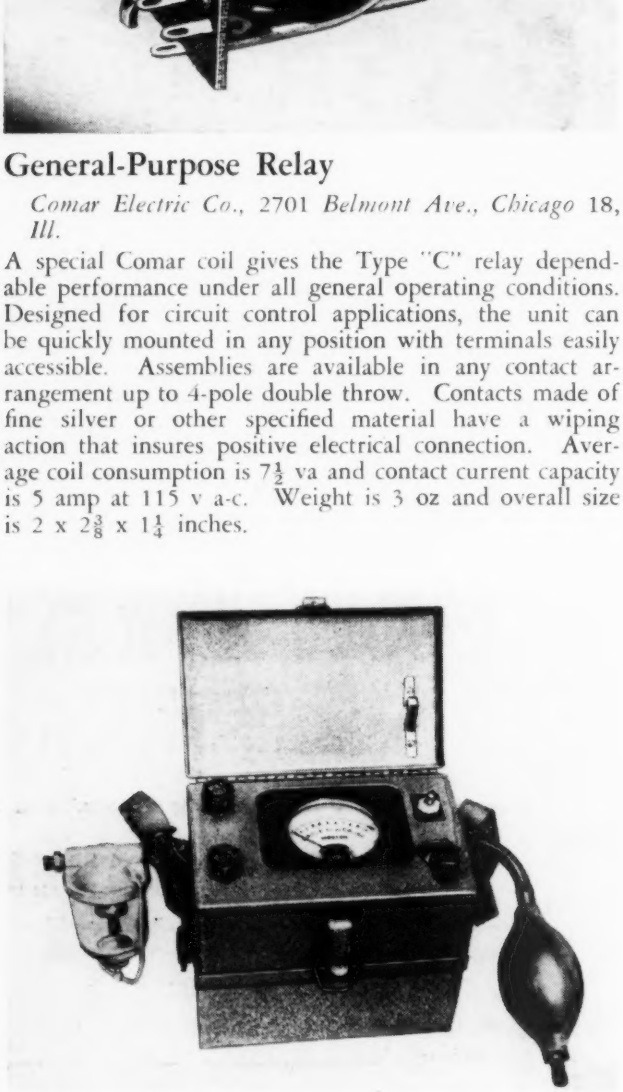
operation of Geiger-Mueller tubes and other types of detectors. An a-c outlet and switch circuit for operating a clock timer permits simultaneous counting and timing.



General-Purpose Relay

Comar Electric Co., 2701 Belmont Ave., Chicago 18, Ill.

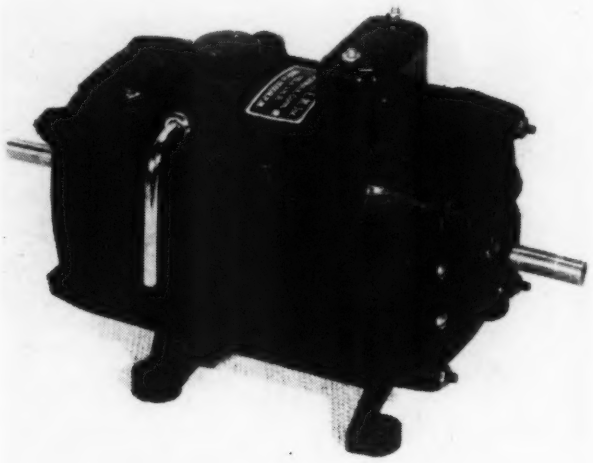
A special Comar coil gives the Type "C" relay dependable performance under all general operating conditions. Designed for circuit control applications, the unit can be quickly mounted in any position with terminals easily accessible. Assemblies are available in any contact arrangement up to 4-pole double throw. Contacts made of fine silver or other specified material have a wiping action that insures positive electrical connection. Average coil consumption is $7\frac{1}{2}$ va and contact current capacity is 5 amp at 115 v a-c. Weight is 3 oz and overall size is 2 x $2\frac{3}{8}$ x $1\frac{1}{4}$ inches.



Combustible Gas Detector

Davis Emergency Equipment Co., Inc., 45 Halleck St., Newark 4, N. J.

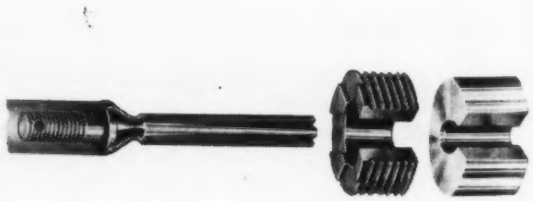
Combustible and explosive concentrations of flammable gases or vapors can be detected by the Model 6 Vapotester. The instrument analyzes gases in a low range up to the lower explosive limit or in a higher range 10 times as sensitive in the toxic range. A sample of the gas-air mixture is ignited on the surface of one leg of a Wheatstone Bridge circuit and the resultant unbalance is recorded on the meter in proportion to the percentage by volume of the gas present. To interpolate the meter readings in parts per million of the gas present, reference is made to a calibration chart that shows what the instrument will read with each of the gases present.



Variable-Speed Motor

Guernet Electrical Machinery, Inc., Box 196, Meriden, Conn.

Designed to maintain constant maximum torque at all speeds, this variable-speed motor is adjustable over a 1,500 to 6,000 rpm speed range. A lever at the side stops or starts the motor and mechanically controls a pair of centrifugal vibrating contacts that accomplish the speed variation. Completely self-contained, the motor is adaptable for drilling, grinding, buffing, polishing, chemical mixing, wire or tape winding and general laboratory work. The unit carries a rating of $\frac{1}{5}$ hp, measures 9 x 7 x 5 in. and operates on a 115 v single phase power supply of any frequency. Models with single or double reduction gears and flexible shafts are also available.

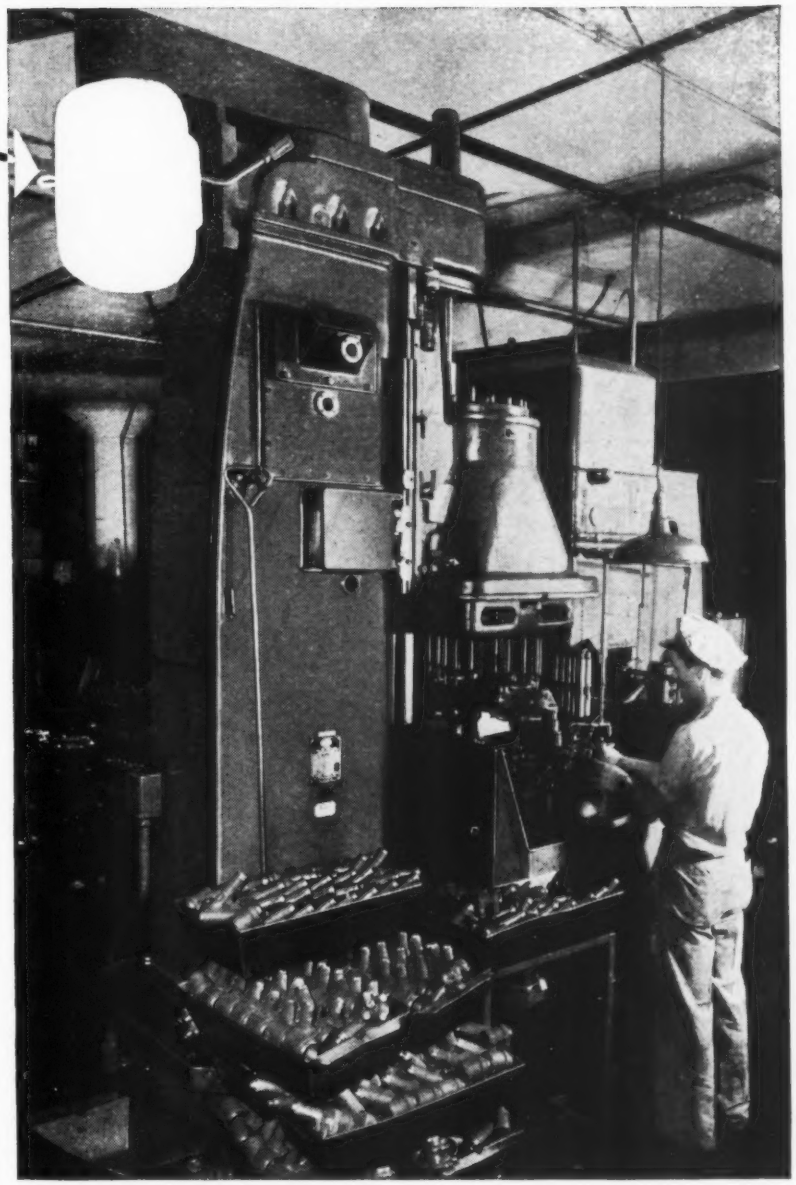


Spline Plug Control Valves

Hammel-Dahl Co., 243 Richmond St., Providence 3, R. I.

Microflo control valves can handle flows from 4 to 2,385 cc per minute. The basic element of the valve is a solid stellite plug $1\frac{5}{8}$ in. long hone fitted in a $\frac{5}{8}$ in. deep stellite seat. The depth of the seat insures streamline or viscous flow just as the plug is leaving the seat. Flow control in

Let Wagner fill this spot... for highest Machine Tool efficiency!

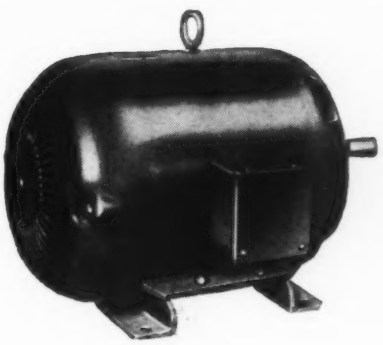


MACHINE tool efficiency is of vital importance in today's stepped-up production schedules. Motor failure means "time out" for the machine, interrupted schedules, and lost profit.

Wagner Quality Motors provide a *reliable* source of power to drive your machine tools—they are famous for their unfailing dependability—and they give you quiet, smooth, vibrationless performance as well!

Many far-sighted machine tool manufacturers have standardized on Wagner Motors. They *know* that dependability and continuity of operation are of paramount importance in a good machine tool . . . and they *know* that Wagner Motors can assure longer life and reduced maintenance costs. If you manufacture or use motor driven equipment, Wagner can furnish a motor that will fit your needs. Users of Wagner Motors also profit by our quick, convenient, nationwide service facilities.

Wagner maintains twenty-nine branch offices, located in principal cities. These offices are manned by trained field engineers who will be glad to help you solve your motor application problems. Write for Bulletin MU-185 for information on the complete line of Wagner Quality Motors.

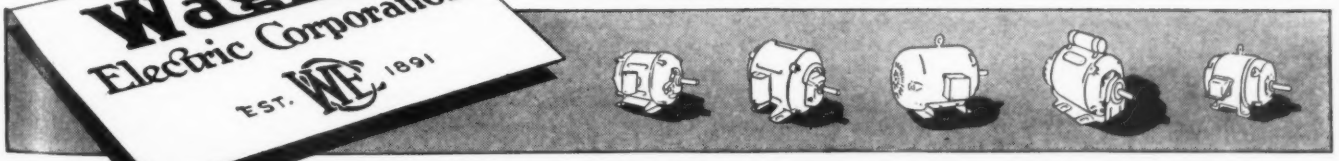


Totally-enclosed Fan-cooled Motor.

Totally-enclosed Non-ventilated Motor.

Wagner Electric Corporation
6406 PLYMOUTH AVE., ST. LOUIS 14, MO., U. S. A.

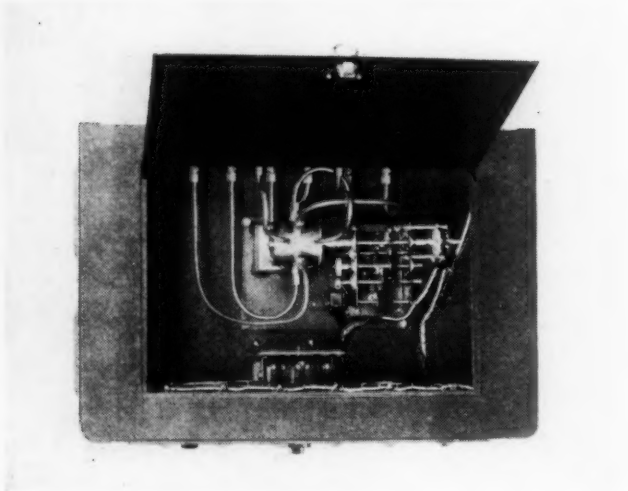
Consult Wagner Engineers on all Electric Motor Problems



M48-6

• ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES • AUTOMOTIVE PRODUCTS •

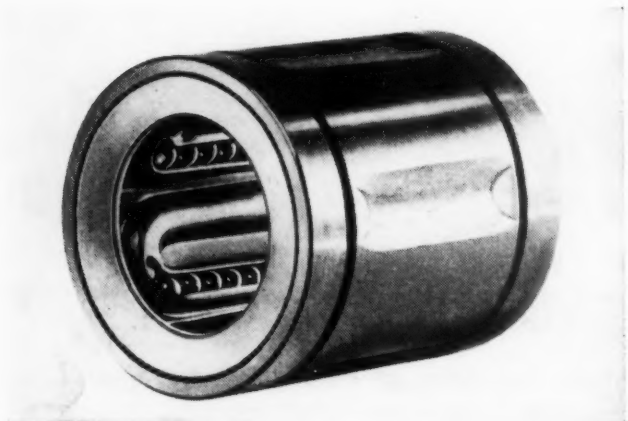
the 1 in. of valve travel is governed by the shape of slots milled in the plug. The seat is held in place by a threaded retainer making it possible to replace the plug and seat with any one of the fifteen different sizes available. A No. 15 spline plug at $\frac{1}{10}$ in. valve lift will pass 9 cc of water per min at 100 psi pressure drop. The valves can be provided in body sizes of $\frac{1}{2}$, $\frac{3}{4}$ and 1 inch.



Gas Atmosphere Selector

Surface Combustion Corp., Toledo, Ohio

Designed for use with a dew point recorder, the Atmosphere Selector can handle gases from as many as six different sources in timed sequence. The equipment consists of a six-way valve with indicating lights, electric time clock and motor so arranged that the source of atmosphere supply to the recorder is automatically switched from one line to the next. Provision is made for skipping one or more lines and returning the inlet valve to the initial line automatically. Between recordings, lines are purged. A typical clock setting for the analyzing frequency is at 30 min intervals so that six samples can be handled in a 3 hr period. Cabinet measures $10\frac{1}{2}$ x 21 x $13\frac{1}{2}$ inches.



Linear Ball Bearings

Thomson Industries, Inc., 1029 Plandome Rd., Manhasset, N. Y.

Series "A" Ball Bushings provide advantages for linear or reciprocating motion applications comparable to those obtained with ball bearings in rotary motion uses. By substituting these anti-friction bushings for plain bearings, the size of entire mechanisms can be scaled down because of the low bearing length-to-diameter ratios required. The reduced friction permits the use of high operating speeds and smaller drive motors, gears, linkages and associated parts. Ball bushings are self-contained units made up of a hardened steel sleeve, a pressed steel ball retainer and a pair of rings which position and secure the retainer in the sleeve. The assemblies now available will fit shafts having $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 in. diameters. In-between and larger sizes are scheduled for future production.

Trip-Proof Coupling

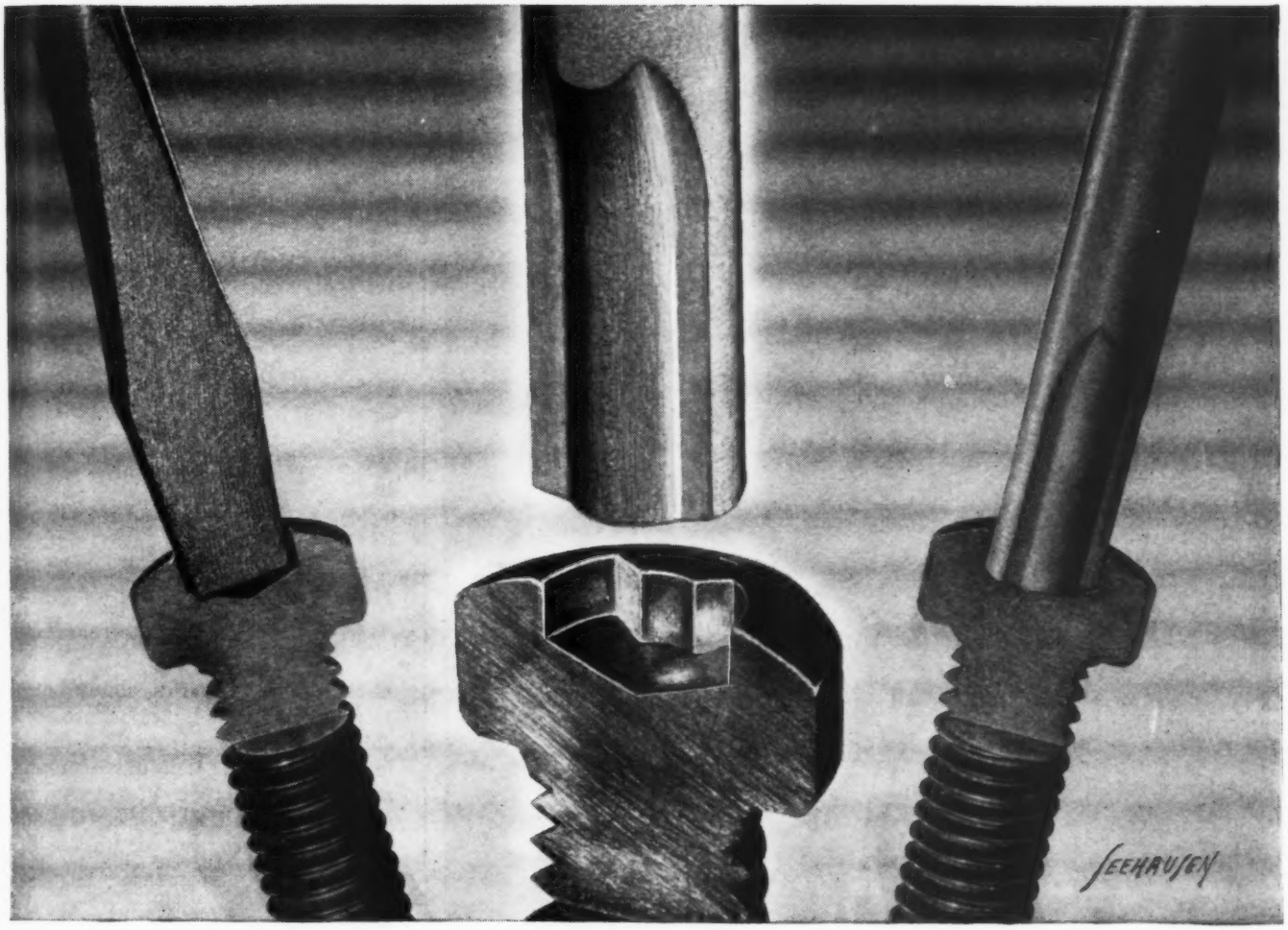
Roylyn, Inc., 718 W. Wilson Ave., Glendale 3, Calif.

A piston type valve built into the Trip-Proof coupling must be in the "shut-off" position before the coupling can be broken. Conversely, the coupling must be locked in its mating nipple before the valve can be opened. This locking action is accomplished by meshing the valve lever with the locking collar of the coupling. Requiring 40 deg rotation for activation, the coupling is easily operated, positive acting, and vibration proof. The unit is especially designed for handling petroleum products, chemicals and other products where spillage is not permissible or desirable. Weighing $11\frac{3}{4}$ lb, the coupling is available in $2\frac{1}{2}$ in. pipe thread sizes with larger units contemplated for future production.

D-C Power Supplies

Condenser Products Co., 1375 N. Branch St., Chicago 22, Ill.

The HiVolt PS-1 is the first of a series of high voltage low current power supplies designed to charge capacitors used in electronic photoflash and spectrographic analysis equipment. A similar unit, the PS-2, is intended for use in radiation counters, oscilloscopes and television receivers. Assemblies are hermetically sealed in lacquer finished lead-coated steel containers that are unaffected by humidity. PS-1 and PS-2 units will transform 118 v a-c 60 cycle current to 2,400 v d-c. Additional models developing 4,000 and 10,000 v are planned for future production. All assemblies measure $3\frac{3}{4}$ x $3\frac{3}{16}$ x $5\frac{1}{2}$ in.; weight is $2\frac{1}{4}$ pounds.



Here's How CLUTCH HEAD *Brings New Safety, New Speed in Line Assembly*

Q. What is the main cause of driver skidding? **A.** *"Ride-out" as set up by tapered driving.*

Q. How does CLUTCH HEAD overcome this "ride-out"? **A.** *By elimination of the tapered recess.*

Q. How does the CLUTCH HEAD engagement differ? **A.** *With straight sides of driver matching straight recess walls.*

Q. What safety benefit results from this engagement? **A.** *No slippage, so no damage to operators or work.*

Q. Does this eliminate need for end pressure? **A.** *Yes. No "ride-out" to combat; no end pressure; no skids.*

Q. Do CLUTCH HEAD users support this skid-free claim? **A.** *Many. Norge says "Cabinet damage eliminated."*

Q. What of this feature as a fatigue factor? **A.** *Effortless driving means more screws driven per day.*

Q. How does the Center Pivot Column add to safer driving? **A.** *It prevents canting by guiding bit into dead-center entry.*

Q. Why is CLUTCH HEAD "America's Most Modern Screw"? **A.** *Because it has features unmatched by any other screw.*

Q. What are these features?

A. *They include a recess engagement to match the ruggedness of the Type "A" Bit construction for driving up to 214,000 screws . . . non-stop; simple 60-second bit reconditioning; the Lock-On for easy one-handed driving, and basic design for common screwdriver operation.*

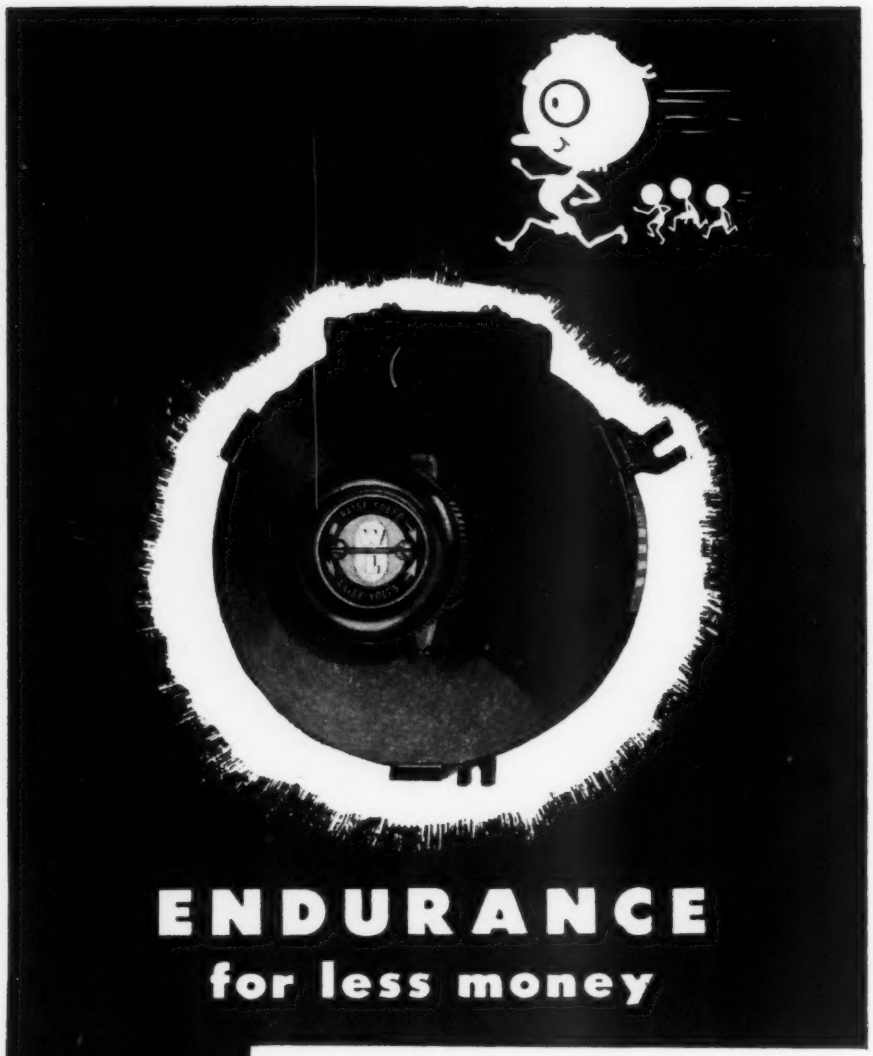
CLUTCH HEAD · SCREWS ·

Q. And how may we check them?

A. *You may check all of these features by sending for package assortment of screws, sample Type "A" Bit, and illustrated Brochure. These will come to you by mail and will give you an understanding why CLUTCH HEAD users report 15% to 50% increases in assembly production.*

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7



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Construction of Ward Leonard Vitrohm Rheostats permits use of smaller sizes

A large number of solid rectangular contacts, imbedded in vitreous enamel on a pressed steel base, fit Ward Leonard Rheostats for high watt capacity and long, continued service. Size for size, no other rheostat will perform a similar duty.

Ward Leonard Rheostats are "Result-Engineered". By modifying a basic design, Ward Leonard can often give you the results of a special . . . for the price of a standard.

Write for Rheostat Catalog. Ward Leonard Electric Co., 63 South St., Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

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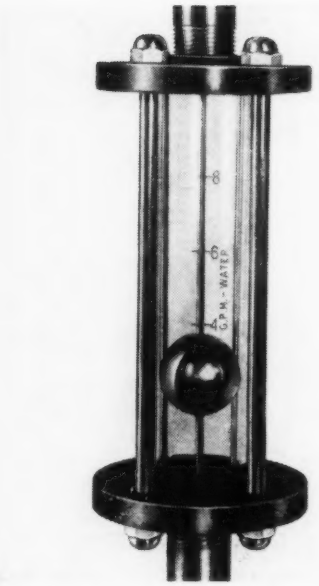
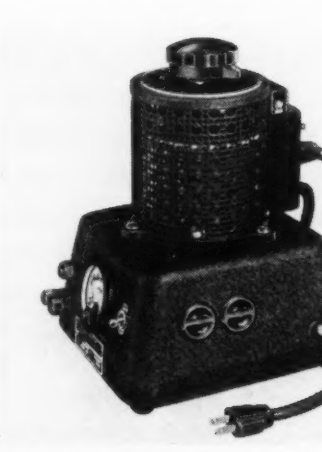


Ball Flow Indicator

Schutte & Koerting Co., Philadelphia 22, Penn.

Useable with lubricating oils and many solvents, ball flow indicators are available in flow ranges from 0.2 - 60 gallons per minute. The units comprise a tapered glass tube with a moving, guided brass ball that acts as the flow indicator. Movement of the ball is confined to the center of the tube by a slender stainless steel rod. Neoprene gaskets are used as seals at each end of the tube. These indicators can be connected in series with pumps, filters, water treating equipment, bearings and cooling jackets to show progressive wear or clogging of equipment. Units are manufactured in all standard pipe sizes from $\frac{1}{4}$ to 2 inches.

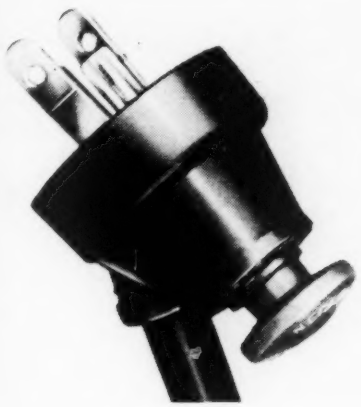


Portable Power Supply

Superior Electric Co., 6107 Laurel St., Bristol, Conn.

Capable of producing a variable a-c output voltage from 0 to 17 percent above line voltage, this portable Voltbox power supply has many applications in the physical and chemical laboratory. Power can be taken from

any or all of the output receptacles and insulated binding posts. The cast aluminum case contains a variable transformer, a voltmeter accurate to 2 percent and a renewable fuse. Two models of the Voltbox are available. Type UC1M is rated at 0-135 v, 7.5 amp, 1,000 va output from a 115 v 50/60 cycle single phase input; type UC2M is rated at 0-270 v, 3.0 amp., 810 va from a 230 v, 50/60 cycle single phase input.



Locking Electric Plug

Neoline, Inc., 130 *S. Hewitt St., Los Angeles* 12, *Calif.*

Quickly installed or removed, this Neolock "105" locking plug has great utility in the industrial or home appliance field. Slight finger-tip pressure on the plunger attached to a sliding wedge forces the prongs tightly against the contacts of the receptacle. Positive contacts are made even in badly worn sockets. The plug is unlocked and easily removed by pulling the plunger. Ease of disassembly makes substitution of this plug for the conventional type a simple operation. Available in any standard color, the Neolock plug is constructed of neoprene that provides resistance to oil, sunlight, and hard usage. Two-conductor plugs are available and 3 and 4 conductor assemblies are scheduled for future production. Load ratings for this 105 series of plugs range from 10 to 60 amperes.

Plastic Tubing

William Brand & Co., 276 4th Ave., New York 10, *N. Y.*

Many applications for electrical insulating sleeving and tubing, once considered beyond the practical limits of thermo-plastic material, are now possible with Turbo Extruded Type REL-16 tubing. Extensive tests have shown that this modified polyvinyl resists heat shock without cracking and endures prolonged heat, 2,400 hours at

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construction
New Contactor has maximum capacity for minimum space, and long life
With a minimum of parts, Ward Leonard's new size #1 a-c solenoid contactor is unusually compact. Assembly in your product is simplified by fact that contactor was designed to meet machine tool requirements. Adaptable to many applications where space is limited. Easy to look at, but doesn't need looking after.
Ward Leonard contactors are "Result-Engineered". By modifying a basic design, Ward Leonard can often give you the results of a special . . . for the cost of a standard.
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By another name

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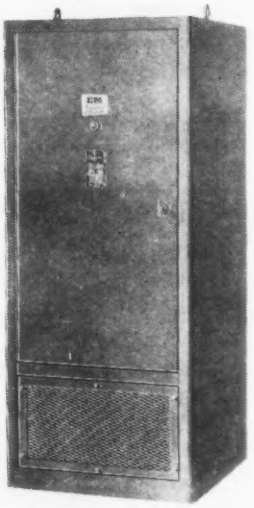
135 C, without sagging, flowing or cracking. Heat shrinkage properties are within practical limits and Turbo REL-16 will not burn or support combustion. The water absorption capacity of this plastic is low and it does not change size during immersion. The dielectric strength of tube samples with 0.020 in. thick walls is 1,600 volts per mil at 28 deg Centigrade.



Electronic Speed Control

Electric Machinery Mfg. Co., Minneapolis 13, *Minn.*

This Regutron rectifier provides excitation and speed control of boiler draft fans, centrifugal pumps, compressors and blowers on which magnetic drives are used. The unit rectifies 3-phase supply current to energize the drive and adjusts the current to hold operating load speed to within plus or minus one percent of selected speed. A small potentiometer is used for automatic or manual speed selection. Other controls guard against effect of overvoltage, under voltage, short-time power failure, and improper operation of tubes or amplifier.

Solenoid Contactors

Ward Leonard Electric Co., 31 South St., Mount Vernon, N. Y.

Solenoid-operated contactors of compact design are available for use as control devices in industrial and commercial applications. Size 1 A C Contactors are adaptable to complex or built-in a-c control panels and as main line, reversing or accelerating contactors on a-c motor controllers for machine tools, pumps and compressors. Other uses include remote control of heater loads and tungsten or infra-red lamp loads. All parts of the assemblies are conveniently arranged on a steel mounting plate of standard NEMA dimensions. Internal

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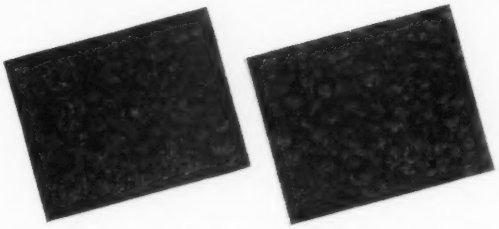

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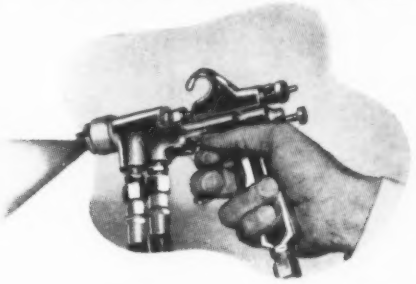
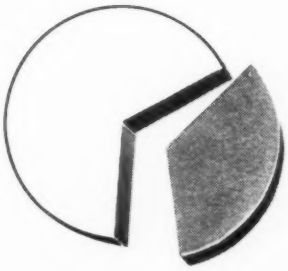
ONE OPERATION!





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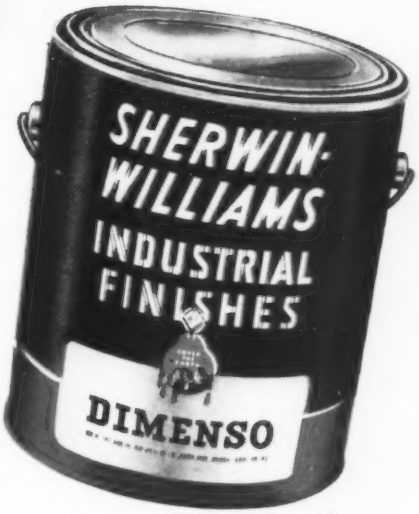

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Cleveland 1, Ohio

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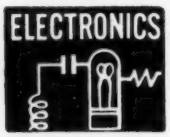

Many new uses for flexible shafts that carry power around any corner have been developed by our engineers . . . in machine shops, electronic, automotive, aircraft, in all industries where power drives or remote control are required. ***Write for Manual P. E.***

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The New BLACK MAGIC *Zinc Black*

Protects Important Parts

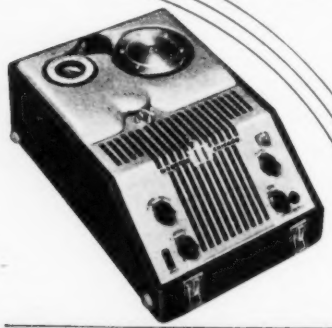
ON THE WEBSTER-CHICAGO WIRE RECORDER

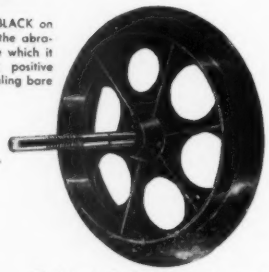
Black-Magic ZINC BLACK is used on the spool of the Webster-Chicago Wire Recorder shown below because it does not build up the diameter and is a good bond for the silk screen painted trade name.

Black-Magic ZINC BLACK on the mandrel resists the abrasion of a felt brake which it engages, affording positive action without revealing bare metal.

Black-Magic ZINC BLACK is the modern treatment for zinc base die castings and zinc fabrications —as an attractive final finish and an effective corrosion and abrasion resistant. It is also an excellent bond for paint, and when so used, it affords full protection for unpainted areas.

Because of these advantages, Black-Magic ZINC BLACK is becoming "standard practice" wherever product sales and service life are important.





Black-Magic ZINC BLACK, used on the take-up reel, resists the abrasion of the magnetic recording wire which rides on the periphery.

Write for the "Black Book" of details on our zinc black and other Black-Magic metal finishes. Also, for a first-hand acquaintance with this zinc black, suggest you send us a product for sample processing without obligation.

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MODERN METAL FINISHES

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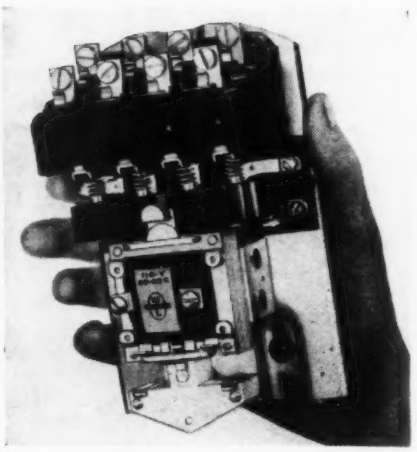
BLACK-MAGIC OXIDE BLACKING SALTS
WITCH-DIP & WITCH-OIL FINAL FINISHES

SILCO *Glass-Base* PROTECTIVE COATING
HEAT TREATING SALTS, CLEANERS, ETC.

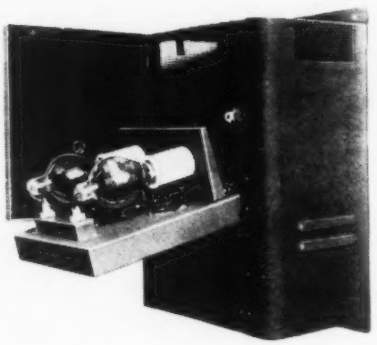


contacts are of the double break silver-to-silver type and are silver brazed to line and load connection terminals. Available with up to four main poles, these contactors have maximum ratings of 7½ hp, 440 - 550 v on 3-phase 60-cycle circuits. Standard coils operate on 110, 220, 440 and 550 v at 25, 50 and 60 cycle frequencies.

Fibre Arc Chamber

N. S. Baer Co., Hillside, N. J.

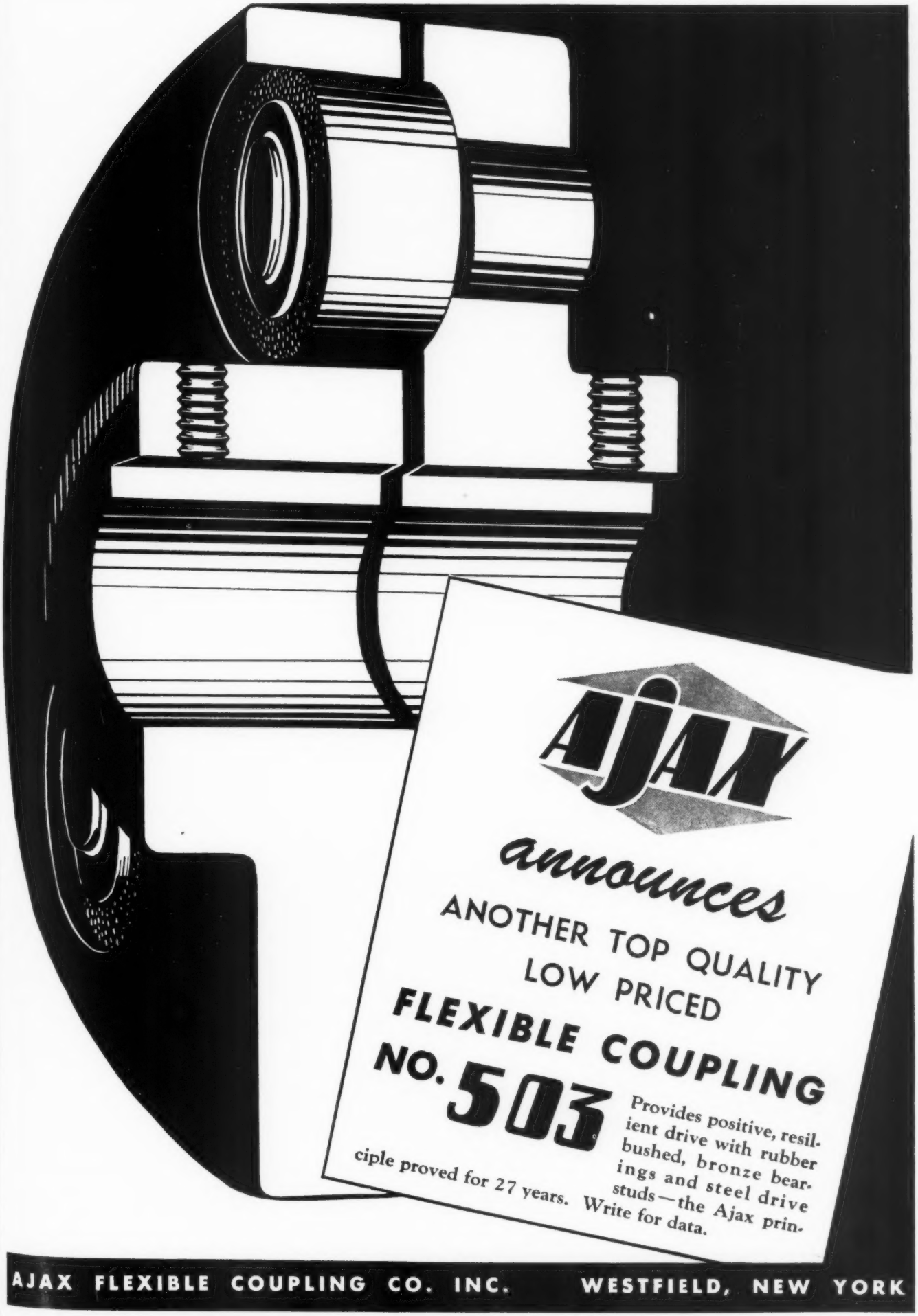
The combined electrical and mechanical strength of vulcanized fiber, when applied to arcing chambers, has contributed to the simplification of circuit breaker construction and to the protection of molded barriers from arc burning. The assembly successfully prevents arc-over on a circuit breaker when a 5,000 amp, 460 v a-c short circuit at 40-50 percent power factor is produced. The dielectric strength is sufficient to prevent breakdown when the applied voltage is twice rated plus 1,000 v or a total of 1,920 volts.



Rectifier

Weltronic Co., Dept. K, 19498 *W. Eight Mile Rd., Detroit* 19, *Mich.*

Known as the Series WR 40-50-60, this electronic rectifier is useful for powering small d-c motors, magnetic chucks and equipment requiring 750 to 2,000 watts. Simplicity of design,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accessibility to parts and full ventilation characterize this equipment. The control panel tilts forward for servicing. Mounted on the front panel are the main line switch, line fuses and time-delay relay that prevents operation of the power tubes until the filaments are properly heated. On the back of the panel are mounted the two power tubes and terminal strips where all connections are made. Rated at 115/230 v d-c; 115/230/460 v a-c, the rectifier is 18 in. wide, 12 in. deep, 24 in. high.

Special Purpose Rubber

B. F. Goodrich Chemical Co., Rose Bldg., Cleveland 15, Ohio

Two special types of Hycar oil resistant rubber are in commercial quantity production. Designated as OR-25 EP and OR-25 NS, the materials have processing properties superior to the regular Hycar OR-25. The NS type differs from the EP in that a different anti-oxidant is added to the former making it non-staining and non-discoloring. The principle advantages of these special types include better extrusion, banding, fusion, and mold flow characteristics, as well as increased building tack for laminated products such as frictioned stocks and calendered sheeting.

Industrial Limit Switch

Micro Switch Div., First Industrial Corp., Freeport, Ill.

Adjustable through 360 degrees, the rotary-action lever arm of this limit switch permits the actuating mechanism a maximum of 90 deg total travel in either direction. The assembly is therefore especially suited for application to the industrial machine tool field. The LMRS die-cast aluminum housing is sealed against dirt and moisture and provides means for standard ½ in.—14 thread conduit attachment. Two basic switches are recommended for use with this housing. Type BZ-2R-A2 has bottom facing terminals; type BZ-2R-P2 has side facing terminals. Switches will cary inductive loads of 10 amp at 110 v, 5 amp at 220 v or 3 amp at 440 v, a-c 60 cycles.

Overlay Welding Rod

Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

Overlays of 67 Rc hardness can be produced on copper and ferrous metals through the use of "EutecRod" 188 gas welding rod. No heat treatment is required as the overlay is applied in a single pass without dilution of the base metal. The alloy has a bonding

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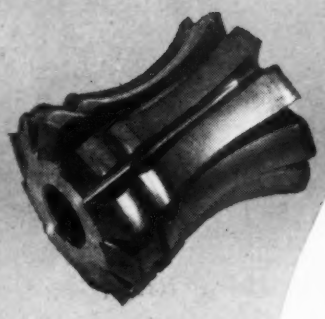

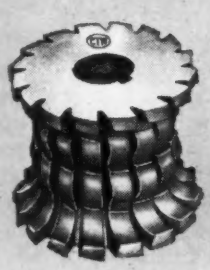

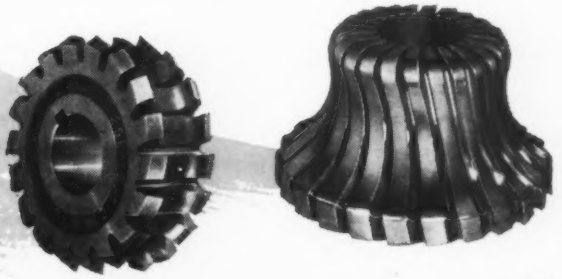

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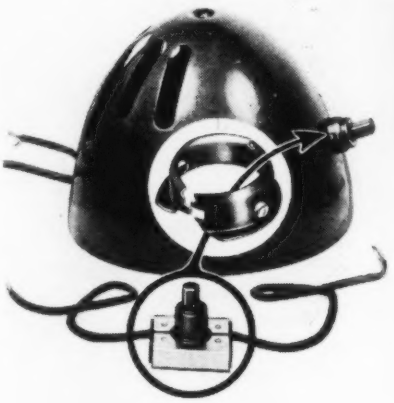
Smith-Blair Inc., S. San Francisco, Calif.

Self-adjusting and self-locking, this Water-Lock rubber ring pipe joint packing is hydrostatically designed to increase its sealing action from line pressure. The ring can be installed quickly without cutting or fitting and used with any joint compound. Working alone without compound it will hold 40-60 lb pressure. Being nonporous, the rubber cannot be a culture point for bacteria or other contaminating elements.



Tubular Speed Clip

Tinnerman Products, Inc., 2041 Fulton Rd., Cleveland 13, Ohio

Two lock washers and a nut are no longer required and appreciable assembly time is saved when this tubular type speed clip is used to assemble a

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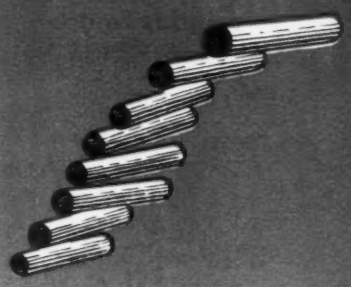
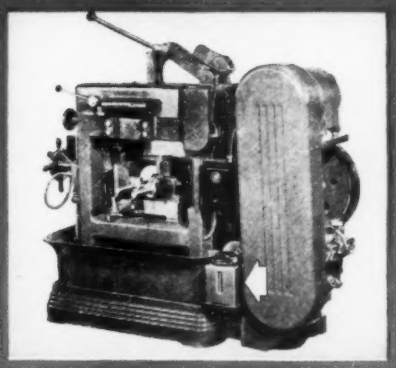
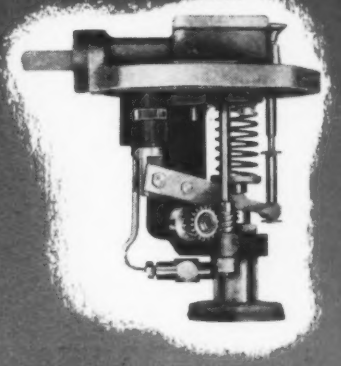


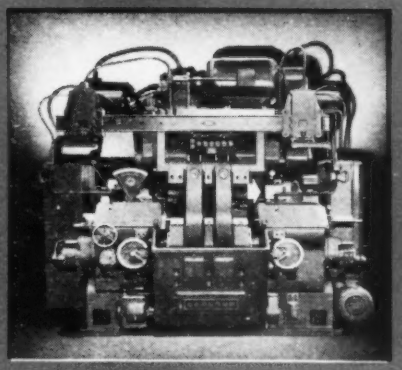


Peerless Mechans-cut Saw. All 22 bearings and slides are regularly oiled by the cyclic lubricator.

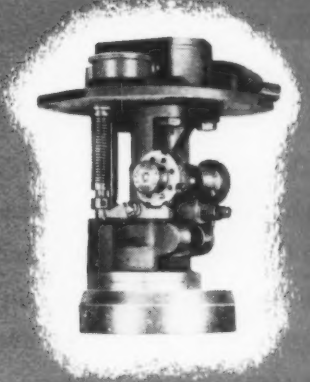


Cyclic lubricator unit discharges 60 drops of oil at 50 pounds pressure every 4 minutes.

TO CRANKSHAFTS



Le Blond 2 LB Line Bearing Crankshaft Lathe. Approximately 50 heavy-duty bearings and ways are constantly oiled by the high-pressure lubricator.



High-pressure lubricator unit discharges 630 drops of oil at 100 pounds pressure every 6¼ minutes.

From raw stock to finished product-whatever operation your machine performs, it will run better on Bijur-oiled bearings. Assuring automatic distribution of clean oil to all bearings *while the machine is running*, the Bijur system insures maximum production while it reduces bearing wear. Built into machine tools, printing presses and sheet metal machinery, this central oiling system effectively lengthens the productive life of the machine. It will pay to talk over your lubrication problems with a Bijur engineer.

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push button switch to the electric fan housing shown in the cut. Hand assembly consists of snapping the clip into the housing hole and pushing the switch into the clip from the inside of the housing. As the switch is installed the sleeve of the switch expands the clip forcing it against the housing. The turned-in edge of the clip seizes the switch sleeve with a compression "bite" that prevents the switch from backing out.

Coolant Pump

The Ruthman Machinery Co., Cincinnati 2, Ohio

An electronic process is used to dynamically balance all rotating parts in the Model 11,029 motor driven coolant pump. Continuous, quiet operation is obtained through the use of twin coolant inlets that reduce end thrust on the shaft. The motor incorporates pre-lubricated ball bearings and is enclosed in a dripproof upper end bell. The pump is of the impeller type wherein there are no metal-to-metal contacts within the submerged portion. Liquids containing reasonable amounts of grit and abrasives can therefore be handled. Capacity at 26 ft head is 40 gpm with a $\frac{1}{2}$ hp motor and 60 gpm with a $\frac{3}{4}$ hp motor.

Thermostat Relay

Sigma Instruments Inc., 70 Ceylon St., Boston 21, Mass.

One method of accurate temperature control uses a sensitive mercury thermostat that switches the coil circuit of a relay; the relay controlling the load. Satisfactory long life from the thermostat requires that the current carried by the tiny electrodes be kept to a minimum, preferably below 4 milliamperes

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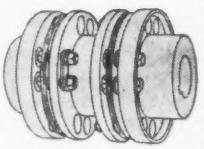

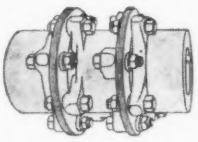

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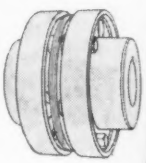

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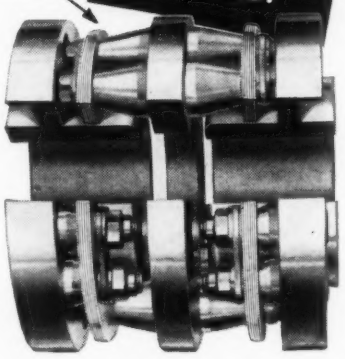

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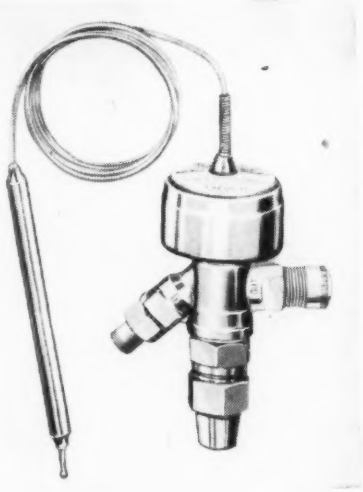
at 115 v. a-c. It is desirable that a-c current be used to minimize plating of the electrodes and contamination of the mercury. The Sigma Series 41 totally inclosed relay is suited for this application. One standard type operates with only 2 milliamp at 115v, a-c in the coil circuit. The relay contacts are suitable for loads typical of this service, such as solenoid valves, incandescent indicator lamps and resistance heaters. Replacement after damage or long service is made easy by plug-in mountings. Illustrated is the Type 41 RO which weighs 3 oz and is 1¾ x 1¼ x 2in. high above the base. This relay in combination with the Amphenol socket, permits screw connection to the relay.



Expansion Valve

Automatic Products Co., Milwaukee 10, Wis.

Refrigerator motor overload protection is provided by a liquid-charged pressure limiting diaphragm unit built into this thermostatic expansion valve. The beryllium copper diaphragm closes a stellite needle valve before the motor becomes overloaded during pull-down or peakload periods. Suitable under all temperature conditions, the A-P 212 valve is adjustable over a 2 to 20 F superheat range. Installation can be in any position and adjustments are accessible at all times. Assem-

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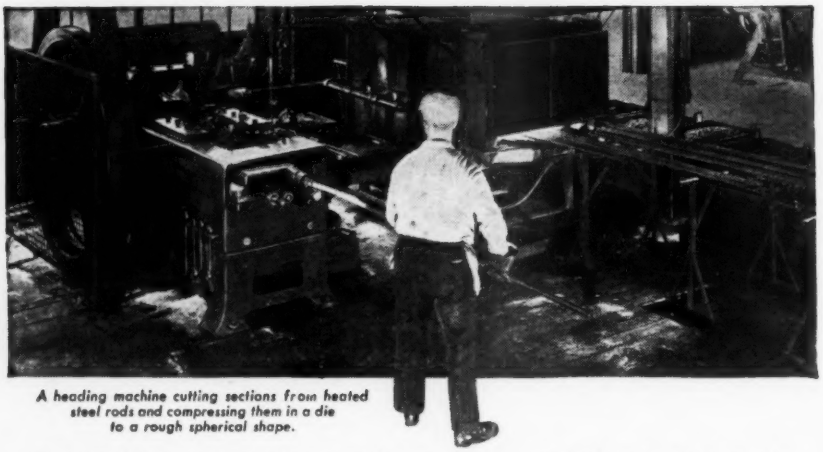

A heading machine cutting sections from heated steel rods and compressing them in a die to a rough spherical shape.

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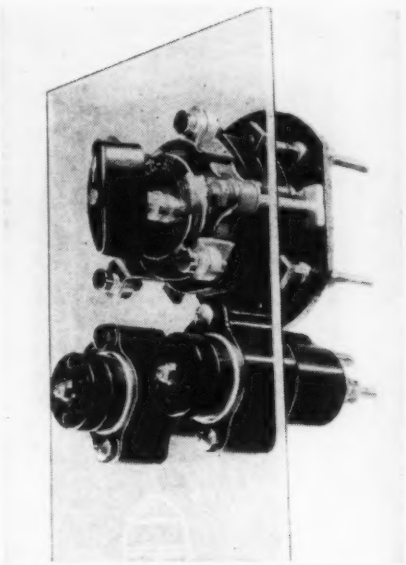
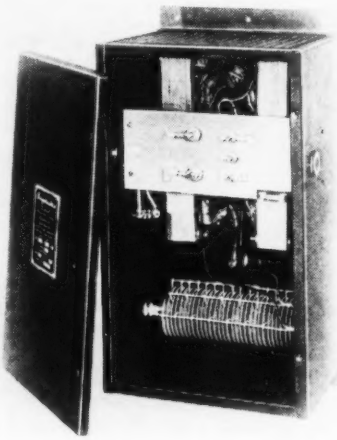


Fused Rotary Snap Switch

Electro Switch Co., Weymouth, Mass.

Switchboard space is conserved by using this compact fused switch. The unit comprises the Type P, Esco high speed rotary snap-action switch and a panel-mounted fuse holder. Standard cartridge fuses are replaceable from the front of the panel. Integral with the fuse holder is a neon-lamp type "blown-fuse" indicator. Switches with ratings of 10, 30, 60, 100 and 200 amp are available.



Constant Voltage Rectifier

La Marche Mfg. Co., 6525 Olmsted Ave., Chicago, 31, Ill.

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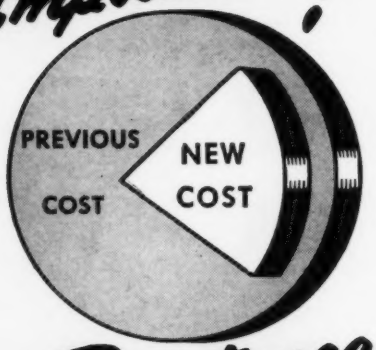

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PROGRESSIVE WELDER COMPANY
3050 E. OUTER DRIVE, DETROIT 12, U.S.A

drops as the current is increased, this unit will maintain or increase the starting voltage until the full amperage has been drawn. Large groups of low voltage d-c magnets and banks of pipe organ electrical systems have been handled by this assembly. Designed as a full-wave bridge type unit, this rectifier is suitable for any a-c frequency and for line voltages from 115 to 230. The pulsating d-c is filtered about 25 percent.

Full Wave Rectifier Tube

National Electronics Inc., Geneva, Ill.

Combining two half-wave rectifiers in one envelope, the NL-604 high voltage tube is specially designed for industrial and electronic motor control applications. Filled with gas and mercury, the tube gives quick starting and uniform characteristics over a broad temperature range. Operation between —10 and 50 C ambient temperature gives full tube life. Rated for full 250 v d-c output at 2.5 amp, the tube has filament requirements of 2.5 v 11.5 ±1 amp and a heating time of 15 seconds.

High Speed Relay

Stevens-Arnold Inc., 22 Elkins St., South Boston, Mass.

An ultra high speed d-c mechanical relay has an operating time of one millisecond. Life expectancy varies from 22 million operations at ½ amp to 100 million operations at ¼ ampere. Designed as a single pole, double throw unit, the relay can be used with resistive or inductive loads. Special tests must be made to insure satisfactory operation with a specific inductive load. Coil and contacts are shielded from each other and mounted in a standard type radio tube container. Coils are wound for d-c use at 18 v, 1,400 ohms or 6 v, 150 ohms.

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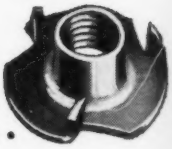

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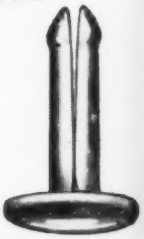

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